PLUMBING

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PREFACE

This book is intended to be an aid to architects, master plumbers, engineers, plumbing inspectors, students, and others interested in plumbing design and installation. It contains information on the latest standard practices recommended by recognized authorities and information concerning methods of design which simplify plumbing for dwelling houses and reduce the amount of venting required in larger buildings. Roughing-in dimensions of pipes, fittings, and fixtures are given, insofar as they have been standardized, together with information on the methods of connecting these parts of a system in a complete plumbing installation. Definitions of plumbing terms have been given at length because of the confusion which exists in their use and the different meanings sometimes applied to the same term. Wherever recommendations are made the reasons therefor are given, these reasons being based on experiment and experience.

Knowledge of the physical laws of the flow of air and water in plumbing pipes has increased rapidly during the past few years following the publication of the results of the intensive research programs conducted at the United States Bureau of Standards and at the Engineering Experiment Station of the University of Illinois. The results of the research work at the United States Bureau of Standards appeared on July 3, 1923 in a report entitled "Recommended Minimum Requirements for Plumbing in Dwellings and Similar Buildings." The book was prepared by the Sub-committee on Plumbing of the Building Code Committee of the United States Department of Commerce under direction of the Secretary, Herbert Hoover. For this reason the report is mentioned herein as the "Hoover Report." The late Professor G. C. Whipple of Harvard University was chairman of the Sub-committee which prepared the report. Partial results of the research work done at the Engineering Experiment Station of the University of Illinois appeared in 1924 as Bulletin 143, entitled "The Hydraulics and Pneumatics

of House Plumbing" by the author of this book. A second bulletin on this subject is now in preparation.

The design and the practice of plumbing are being affected by the preparation of standards which are being published periodically by the Division of Simplified Practice of the United States Department of Commerce, and by the adoption of plumbing codes based on published results of research, particularly on the Hoover Report. Among the comprehensive codes recently adopted is the code recommended by the Illinois State Department of Public Health for adoption by Illinois Municipalities. This code was prepared by the author of this book under the direction of the Illinois State Department of Public Health and in conference with a committee of the Illinois Master Plumbers Association. It was in the preparation of the details of this code, and in the pursuit of research work at the University of Illinois, that the need for a new and complete text on plumbing was felt by the author.

Thanks are due to the many manufacturers of plumbing materials who so generously lent aid in assembling information and illustrations. The author is grateful also to C. D. Brownell, of Champaign, Illinois, Chairman of the Research Committee of the Illinois Master Plumbers Association, whose personal experience and valuable library were freely consulted.

The book is not the last word on plumbing for that will never be said. It is perhaps a justifiable addition to the texts available on the subject, because it contains the results of the epoch-making researches which have been published recently.

H. F. B

URBANA, ILLINOIS,
December, 1927.

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PLUMBING

CHAPTER I

THE ELEMENTS OF PLUMBING

1. The Plumber.—The advance in the scale of ideals wi
regard to plumbing has been so great that the design, instal
tion, and maintenance of pipes and fixtures is no longer the wo
of the handy man, the lead worker, or the jack-of-all-trades.
plumber, to deserve the title and to receive the respect of l
associates, must be trained in the art of his trade and the manip
lation of his tools. He must have knowledge of the natu
physical laws affecting the materials he uses and the installatio
he makes, legislation affecting plumbing, and business metho
and procedure. In brief he must be a mechanic, a physicist,
architect, an engineer, a builder, and a business man.

2. The Purpose of Plumbing.—A plumbing system is install
in a dwelling or other building for the primary purpose of co
venience and comfort. The supply pipes of the system bring
wholesome water supply and the drainage pipes carry off t
used water. Sanitation and health as well as convenience a
comfort, are served, and, because of the possible damages
health resulting from impure water and improper drainag
care and knowledge must be exercised in the installation
plumbing.

A wholesome water is supplied to most buildings by t
municipality. The quality of the water is under the supervisi
of the local and state health authorities. The waste water
discharged into the common sewers where it is also cared for l
governmental agencies. Where the public water supply is n
wholesome or no public water supply is available or where
common sewers are available, private filtration of water a
attention to proper sewage disposal become necessary and t
plumber is called upon for information, equipment, and servi
in these matters.

The householder at home and the citizen in the public building are accustomed to and demand types of plumbing fixtures and installations unknown a generation ago. The condition of plumbing even in so short a time ago as the span of one human life would not be tolerated today; its installation would be illegal. In spite of the many outstanding advantages of plumbing installations some disadvantages sometimes accompany the installation of pipes in a building. The presence of pipes in a building present two dangers: one from the bursting of pipes under pressure which may destroy property, and the other, more subtle but none the less real, the escape of gases or sewage from the drainage pipes, which is dangerous to life and health. With care in design and maintenance both of these objections to the presence of plumbing in a building can be overcome.

3. Objections to Plumbing.—The danger from bursting pipes can be minimized by the use of proper materials, proper design, and good workmanship in installation. It is a real danger to property and must be carefully guarded against. The danger to health from sewer gas resulted in a bitter controversy over its reality. Cases are cited of men who have worked in sewers for long periods of time without deleterious effect upon their health, and cases are cited of the asphyxiation of men entering a manhole. The situation might be summed up in the statement that there are no scientific data to prove or disprove the so-called dangers from "sewer gas," but in view of the uncertainty of the matter and the extreme danger which may result from admitting such gases to our homes, the greatest care should be exercised in excluding these gases. Not only may the odors be dangerous but the thought of their presence is repugnant and unpleasant and hence they must be excluded.

4. Purpose of Traps.—Odors, insects, and vermin from the sewer are prevented from passing into a building through the plumbing pipes by means of traps which are filled with water. It follows, therefore, that every opening from a building into a plumbing system which is connected to a sewer pipe should be trapped in such a manner as to maintain a permanent seal.

The maintenance of the seal of the trap offers difficulties which add materially to the cost of plumbing installations. The seal in a trap may be destroyed by evaporation, by blowing or sucking out the water as a result of the variations in pressure in the plumbing system, or the seal may be lost when water, discharging

through the trap at a high velocity, does not fall back sufficiently to maintain a seal in the trap.

5. Purpose of Venting.—The purpose of a vent pipe is to conduct air, at atmospheric pressure, to the lower leg of a trap, *i.e.* the portion of the trap nearest the sewer. This connection to the outer air so reduces the effects of high or low pressures in the plumbing system as to aid in maintaining the seal of the trap.

No certain and safe method has been devised to prevent the evaporation, in time, of water from any trap. The evaporation is so slow compared with the frequency of the use of fixtures in occupied premises that the seal is renewed with sufficient frequency to assure its maintenance. In unoccupied premises the traps should be emptied of water and refilled with kerosene oil or other material which evaporates slowly. Unfortunately, vent pipes serve to increase the rate of evaporation from traps as they furnish a constantly changing supply of fresh air to the surface of the water in the trap.

6. Plumbing Codes.—The installation of improper plumbing may affect the health of the occupants of the building and create a focal center of disease which will have an undesirable effect upon the public health. Such a situation is of sufficient interest to the public to require the regulation of plumbing by law. The police power of the state is invoked and upon this principle is based the right of the government to regulate the minute details of plumbing by means of plumbing codes. There are very few cities in the United States which do not have some sort of plumbing code and an inspector to enforce its provisions.

The aim of the plumbing code should be to cover every possible contingency which may arise in the installation of plumbing. A complete plumbing code is a lengthy document. Its enforcement is legal under the police power of the state and any builder should assure himself that his plans are in accordance with the requirements of the code. It must be admitted, unfortunately, that all plumbing codes are not perfect and that requirements are sometimes made which are unreasonable, unjustified, and harmful. When, in the comparison of two codes, it is found that one stipulates that a certain thing shall be done and the other positively prohibits it, one or the other must be wrong. Plumbing codes are being improved, and during the past few years much attention has been given to their improvement. The credit for this situation can be given to Herbert Hoover,

Secretary of the U. S. Department of Commerce, because of the preparation, under his direction, of the "Recommended Minimum Requirements for Plumbing in Dwellings and Similar Buildings," hereinafter known as the Hoover Report. This contains a proposed standard plumbing code. A series of articles interpreting this code will be found in *Plumbers Trade Journal*, as follows: Jan. 15, 1925, page 146; Mar. 15, 1925, page 530; Apr. 15, 1925, page 732; May 1, 1925, page 828; June 15, 1925, page 1135; July 1, 1925, page 17; Aug. 1, 1925, page 217; Aug. 15, 1925, page 306; also Vol. 77, pages 370, 473, 556, 650, and 746, for the year 1924; and Vol. 76, page 1018, 1924. There is a discussion of the tentative proposals in the same magazine, Vol. 73, page 734, 1922.

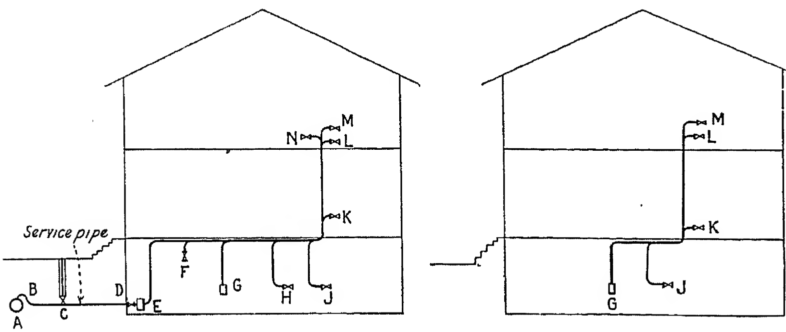
7. **The Simplicity of Plumbing Systems.**—A plumbing system reduced to its simplest terms would consist of one supply pipe leading to a fixture and one drain pipe taking the waste water away from this fixture. As the number of fixtures is increased the branching of the supply and drainage pipes is increased. As the kinds of water to be supplied are increased the complication of the supply piping is increased. Most fixtures have at least two supply pipes, one with hot water, the other bringing cold water. In some buildings soft water, iced water, and other supply pipes may be installed. When each water-supply system is considered independently the piping arrangements can be more easily understood and appear more simple.

An increase in the number of fixtures increases the complication of the drainage pipes and frequently requires the installation of vent pipes. When the purpose of these supply, drainage, and vent pipes is understood and each system is considered independently of the others a plumbing system, like most other things which are understood, appears simple and easily comprehensible.

8. **Water-supply Pipes.**—The water supply for a city home is ordinarily delivered through a pipe in the street. The pipe in the street is usually of cast iron, seldom less than 4 in. in diameter and usually larger. To this pipe, called the street main, is connected a galvanized-iron or lead pipe, called the service pipe, as is illustrated in Fig. 1. A valve, sometimes called the corporation cock, is placed close to the connection between the service pipe and the water main. Another valve is sometimes placed near the curb. This may be called the corporation cock or sometimes the curb cock. The curb cock is used principally to

turn water on and off without entering the building served. The service pipe continues through the basement wall of the building and usually terminates in a "stop-and-waste cock" near the basement wall and on the inside of the building. This "stop-and-waste cock" should be installed on the lowest point in the water supply piping in the building so that when the valve is closed *all* of the water in the supply pipes can be drained out.

The plumbing system within the building starts from this main valve or stop-and-waste cock. Figure 1 shows a simple layout of the cold-water pressure pipes for a small dwelling house. A



Cold-water supply pipes. Hot-water piping system.

A, street main; *B*, lead goose neck; *C*, curb of corporation valve; *D*, main or stop-and-waste valve; *E*, meter; *F*, sill cock or garden hose connection; *G*, hot-water or furnace coil, *H*, basement water closet; *J*, laundry trays; *K*, kitchen sink; *L*, bathtub; *M*, wash basin *N*, water closet.

FIG. 1.—Diagram showing water-supply pipes in an ordinary dwelling.

simple arrangement of hot-water supply pipes for the same building is shown also in the same figure.

9. Drainage and Vent Pipes.—When water is supplied to a building, provision must be made to remove the waste water from the building. The pipes for this purpose are classified as drainage pipes. From many points of view their design and operation are the most difficult to understand because of the complications involved in the necessity for maintaining proper slopes for drainage and self-scouring velocities, proper pipe capacities, and proper sizes and arrangements of vent pipes to prevent the development of high air pressures in the plumbing pipes.

Water falling through vertical pipes and flowing through the horizontal drainage pipes will entrap, compress, and rarefy air. The air, in its attempts to escape from the vacuum or the pres-

sure thus created may break the seals of traps unless adequate vent pipes have been installed. Vent pipes and drainage pipes are sometimes so closely related that they are sometimes classified together.

The sizes of vent pipes, their number, location, and other details have been determined for many years in the past as a result of the individual experience of different architects and plumbers, resulting in many differences of practice in various cities. Tests recently made at the U. S. Bureau of Standards,[1] and at the University of Illinois have thrown much light on the question of venting and have made possible more intelligent design of the drainage and vent pipes of a plumbing system.

In the small dwelling shown in Fig. 1, it is possible to install all of the plumbing without vent pipes. Such an installation is shown in Figs. 102 and 111.

10. Definitions.—An understanding of the technical and trade terms used in plumbing is essential to the understanding of the description of plumbing principles and design. Definitions of a large number of terms are given in Appendix II. Other unusual or ambiguous terms are defined where first used. Reference to them will be found in the index.

11. Installation of Plumbing.—The installation of plumbing pipes, called the "roughing-in," proceeds simultaneously with the erection of the building, since most of the pipes are concealed in the floors and walls thereof. The pipes must, therefore, be installed before the floors and walls are completed. Because of the necessity for correct installation the plumber must be able to read architectural drawings and to make sketches and sometimes drawings of his own to supplement the plans of the architect.

Usually the first step in the installation of plumbing is the connection of the service pipe with the water main, and the house sewer with the public sewer. The supports for the stacks are then placed and the stacks erected as the building rises. Water supply and drainage pipes are placed simultaneously, the branches following closely on the erection of riser pipes and stacks. All of the roughing-in should be completed before the walls are lathed or flooring laid. Fixtures, except built-in bathtubs and certain special fixtures, are installed after the completion of the flooring and plastering. Their installation, called the finishing, is among the last things done in the completion of a building.

[1] References are placed at the end of each chapter.

References

1. "Recommended Minimum Requirements for Plumbing in Dwellings and Similar Buildings," U. S. Dept. Comm., July 3, 1923. Known as the Hoover Report.
2. "The Hydraulics and Pneumatics of House Plumbing." Bull. 143. Engineering Experiment Station, Univ. of Ill., 1924.

CHAPTER II

WATER SUPPLIES

12. The Public Water Supply.—In most cities today there is a public water supply so arranged that an adequate amount of safe water under a satisfactory pressure is to be found in a pipe in the street near every building. In most cases the citizen can feel so assured of the safety and constancy of the public water supply as to depend upon it entirely for his comfort and convenience and for the operation of all of the plumbing fixtures which he may wish to install.

Pressure.—The pressures maintained in the water mains in most cities, which are not excessively hilly, range between 30 and 80 lb. per square inch. A pressure of 30 lb. per square inch in the main in the street is somewhat low but is sufficient to supply water to an ordinary dwelling. It is usually insufficient, however, in a section containing apartment buildings or other buildings over 40 to 50 ft. high. In rough topography higher pressures are maintained in pipes on the lower streets but pressures much over 100 lb. per square inch will demand special attention in the maintenance of the plumbing.

Before a building is erected the builder should be certain that the water pressure is sufficient to supply the highest service in the building at the desired rate. In a location where the pressure of the public water supply is insufficient it will be necessary to install pumping equipment. If the pressure fluctuates above and below the desired amount an elevated storage tank will supply water during the period of deficient pressure.

Quantity or Demand.—The rates of demand for water vary greatly between different cities, as is shown in Table 1. The figures in the table indicate the total consumption for all purposes and will differ greatly for any particular building or for any individual purpose. The percentage which the demand for different purposes may bear to the total demand is estimated in Tables 2 and 3. The rates of supply to individual fixtures are stated in Table 35. Knowledge of the rate of demand is essential to the

TABLE 1.—TOTAL WATER CONSUMPTION OF CERTAIN CITIES
(From Report of Committee, American Waterworks Association, 1915)

City	Population in thousands	Per cent metered	Consumption, gallons per capita per day
Tacoma, Wash.	100	11.6	460
Norwich, N. Y.	8	0.7	278
Erie, Pa.	72	3.0	218
Grand Rapids, Mich.	90	46.7	176
Jersey City, N. J.	300	14.5	147
Mt. Vernon, Ind.	5.8	9.0	127
Lancaster, Pa.	60	34.6	121
Macon, Ga.	42.5	54.0	115
Hollywood, Mass.	40	100	113
Merrill, Wis.	8.7		105
Louisiana, Mo.	4.86	15.8	98
Burlington, Ia.	24.3	4.5	93
Corning, N. Y.	14.9	99	83
Madison, Wis.	27	99.2	79
Pine Bluff, Ark.	16	100	72
Tampa, Fla.	65	23.5	67
New Orleans, La.	360	99.7	57
Iron Mountain, Mich.	10	45.0	52
Green Bay, Wis.	27	73.8	45
Woonsocket, R. I.	47.5	95.6	32

TABLE 2.—RATE OF WATER CONSUMPTION FOR VARIOUS PURPOSES
(Expressed as percentages of rate of consumption for all purposes)

Purpose or use	Percentage of total daily consumption		
	Minimum	Maximum	Average
Domestic	20	50	35
Commercial and industrial	10	50	30
Public	5	15	10
Leakage and waste	15	40	25
Total	50	155	100

TABLE 3.—WATER CONSUMPTION RATES FOR SPECIAL PURPOSES
(From Report of Committee, American Waterworks Association, 1915)

City	Population in thousands	Gallons per day per meter			
		Domestic	Industrial	Commercial	Public
Altoona, Pa	55.5	155	12,370	1,486	
Beloit, Wis	18	116	44,000	311	2,436
Corning, N. Y	14.9	354	10,420	430	1,712
Fort Smith, Ark	28	114	4,855	2,233	2,673
Holyoke, Mass	60	1,948	4,990	4,990	3,177
Jefferson City, Mo	13.5	147	32,560	448	2,830
Jersey City, N. J	300	1,500	7,570	500	14,700
Kokomo, Ind	20	121	3,733	8,550	1,907
Madison, Wis	27	187	1,988	298	2,076
Marinette, Wis	14.6	66	2,430	568	785
New Orleans, La	360	166	(1)	3,617	2,841
Portsmouth, Va	75	143	11,127	187	2,150
Quincy, Ill	38.6	143	4,583	329	1,295
Richmond, Va	23	107	4,937	2,953	17,071
Rochester, N. Y	250	183	11,425	6,777	8,040
Scottdale, Pa	8.5	540	15,930	1,060	6,700
St. Louis, Mo	730	1,127	17,679	1,959	4,608
Spokane, Wash	104	2,186	31,400	3,600	59,840
Washington, D. C	353	189	27,348	2,500	4,017
Wichita, Kan	54.5	104	3,923	560	2,162

[1] Included in commercial.

proper design of collecting works for a water supply, and knowledge of the variations in the rate of demand are essential to the proper design of pumping stations, reservoirs, and distribution systems, but the citizen about to construct a building to which a public water supply is available need, ordinarily, give no thought to the quantity or quality of the public water supply so long as the supply is endorsed by the constituted health authorities.

Quality.—The sanitary quality of the public water supply is usually investigated by the constituted health authorities and is either condemned or endorsed by them. Where the sanitary quality is unsatisfactory, or the water is too hard, or it stains fixtures, or corrodes pipes, or is otherwise unsatisfactory

purification must be resorted to. The filtration of water to improve the sanitary quality and to prevent other difficulties is explained in Secs. 103 and 104. The softening of water is explained in Sec. 108, and the removal of corrosive qualities is discussed in Sec. 214.

13. Connection of Service Pipe to Street Main.—Water is obtained from the street main by making a connection between the street main and the private service pipe by means of a lead "goose-neck" connection illustrated in Fig. 2. This consists of a piece of lead pipe, about 18 in. long, to one end of which has been soldered a brass nipple threaded to connect with wrought pipe. To the other end there has been soldered a connection for a brass

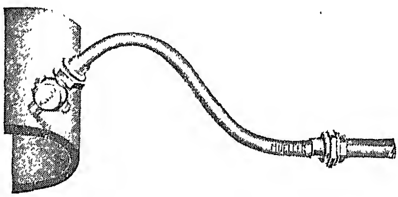


FIG. 2.—Lead "goose-neck" with brass fittings. (*Courtesy Mueller Co.*)

union. A brass valve, usually of the ground-key type, called a "corporation cock," is either tapped or driven into the street main and the lead goose-neck is connected to this valve by means of the brass union. The goose-neck should not be laid straight. It should be looped as shown in Fig. 2 so as to allow for movement between the street main and the service pipe. The driving of the corporation cock into the street main is common but is not the best practice. It should never be done where the water pressures are high and under all conditions the tapped connection is better.

Large buildings are sometimes provided with two service pipes connected to different water mains or even to different points on the same water main so that if the water is shut off one of the mains or anything goes wrong with one service the building will still be supplied with water. The water-supply pipes within the building should be cross-connected to each service pipe and each service pipe should be provided with a check valve to prevent the drawing of water from one service connection to the other through the building.

The insertion of the corporation cock into the street main can be done while the water in the main is under pressure by means

of a special tapping tool.[1] In some cities the tap is made by the waterworks department and in others it is made by the plumber. It is generally considered unsafe to bore a hole larger than 2 inches in a water main. Where service pipes larger than 2 in. are desired a number of taps should be used as illustrated in Fig. 3. The total number of taps should have the same or a larger hydraulic capacity than the service pipe. This can be determined from Table 37.

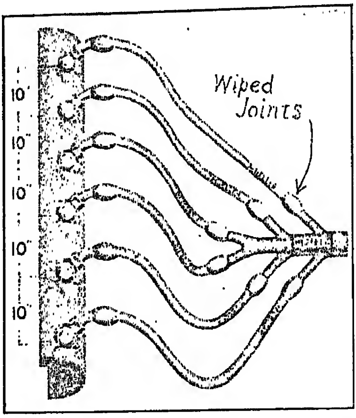


FIG. 3.—Multiple goose-neck connection. (*Courtesy Mueller Co.*)

14. The Private Water Supply.[2]—Where no public water supply is available or where its quality or quantity is unsatisfactory it will be necessary to seek a private source of supply. Private water supplies may be obtained from: (*a*) wells or underground galleries, (*b*) cisterns to collect rain water, (*c*) springs, or (*d*) surface streams. These are named approximately in the order of their relative usefulness. The development of any of these sources of supply requires, in many cases, skill and experience to assure success.

Pressure.—The pressure at which water must be delivered, for all but fire protection, in private supplies is fixed by the difference in elevation between the pump or reservoir outlet and the friction in the pipe lines for maximum rate of demand. Where the pump or reservoir is below the highest outlet on the pipe lines or plumbing system the pipe friction, expressed in feet of water, is added to the difference in elevation. Where the pump or reservoir is higher than the outlet the friction head is subtracted from the

difference in elevation to determine the available pressure at the outlet. The pressure in pounds per square inch to raise water any height is given in Table 4, and information on the method of computing the friction in pipe is given in Sec. 38.

TABLE 4.—PRESSURE IN POUNDS PER SQUARE INCH CORRESPONDING TO VARIOUS HEIGHTS OF WATER COLUMN IN FEET

Head in feet	Pressure in pounds per square inch	Pressure in pounds per square inch	Head in feet
1	0.434	1	2.304
2	0.868	2	4.608
3	1.302	3	6.912
4	1.736	4	9.216
5	2.170	5	11.520
6	2.604	6	13.824
7	3.038	7	16.128
8	3.472	8	18.432
9	3.906	9	20.736
10	4.340	10	23.040

To find pressure in pounds per square inch multiply the head in feet by 0.434.
To find the head in feet multiply the pressure in pounds per square inch by 2.304.
One cubic foot of water at 32° F. = 62.418 lb., at 62° F. = 62.355 lb
One gallon of water weighs 8.33 lb.

Quantity or Demand.—The average and maximum rates of demand for private supplies are usually less than for public supplies because the private supply is used only for special purposes such as domestic, institutional, or industrial; whereas the public water supply must deliver water for all purposes. The rates of consumption for special purposes are difficult to predict with accuracy, but some information of value is given in Tables 2 and 3.

15. Wells.—Infallible rules cannot be given with regard to the location or depth of a well to assure the finding of a satisfactory water supply either in quantity or quality. Experience with wells in the neighborhood is the best guide and a knowledge of the local geology and topography is an essential aid. In general, wells should not be constructed within 50 to 100 ft. of privies or leaching cesspools and locations on hillsides below privies or cesspools should be avoided. The fact that the top of a well is on a hillside above a privy or cesspool is no assurance that the

water is safe from contamination. If the bottom of the well is higher than the source of contamination all danger is quite remote.

Three types of wells are in use for private supplies: the dug well, the driven well, and the drilled well. These are shown in Fig. 4. The details of the connection between the base of the

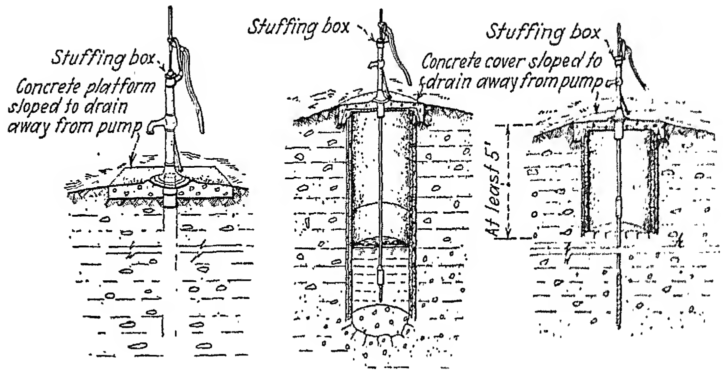


FIG. 4.—Methods of well construction. Recommended by the U. S. Public Health Service. (*Public Health Report Reprint* 952, 1924.)

pump and the top of the well are shown in Fig. 5. This figure is taken from the recommendations of the U. S. Public Health Service in Public Health Reports, 1924, *Reprint* 952. The dug well, as the name indicates, is excavated by means of a shovel. Such wells are usually circular, 3 or 4 ft. in diameter, and are rarely over 50 ft. deep. Dug wells are classified as shallow wells. They should be lined with masonry blocks or stones laid up without mortar in the joints except near the top of the well. Careful protection should be provided at the top to avoid contamination from surface water and drippings which may fall back into the well.

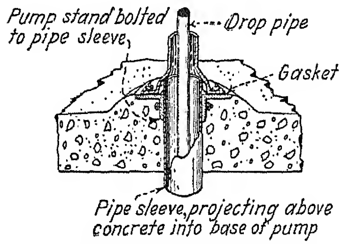


FIG. 5.—Detail of construction at tops of wells shown in Fig. 4.

A driven well is constructed by driving into the ground a pipe, the lower end of which has been drawn to a point, and the sides of which have been perforated for a short distance above this point. A 1¼- or a 2-in. galvanized-iron pipe, perforated with 1,500 to 2,000, 1⁄16- to ⅛-in. diameter holes near the lower pointed end

will supply water at the rate of about 5 gal. per minute. Larger pipes with more holes should supply more water but they are more difficult to drive. The diameter of the holes should not be increased but their number can be increased indefinitely.

The pipe is driven into the ground by successive blows of a wooden or protected maul or other instrument which will not flatten the upper end of the pipe. Additional lengths of pipe are coupled on to the lengths already driven in order to reach the desired depth. Such wells are best constructed in sand or other soft porous material. They cannot, ordinarily, be depended upon to supply a large quantity of water. Such wells are seldom driven to depths greater than 30 to 50 ft., and are, therefore, classed as shallow wells.

The drilled well is used for greater depths than can be attained by either the dug or the driven well. Drilled wells assure water of better sanitary quality and greater quantity than can be expected from shallow wells. The construction of deep, drilled wells requires special well-drilling tools and equipment which are described in books upon the subject.

16. Well Casing.—The diameters of casing used in deep wells vary from 3 to 24 or 36 in. or even larger. A common size of casing for a well to deliver 100 to 200 gal. per minute is around 6 to 12 in. There is no limit to the depth of the well, the rule being to drill until water is encountered. Since the cost of drilling the well increases very rapidly with the depth, the cost of drilling or of pumping finally sets the limit on the depth of the well. The casing is constructed of extra heavy metal designed for the purpose.

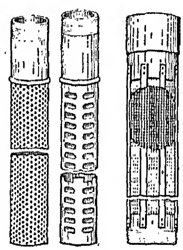


Fig. 6.—Well screens.

17. Well Screens.—The screen, which goes in the bottom of the well, is usually made of brass and is an expensive item in the cost of the well. Types of well screens are illustrated in Fig. 6. Well screens must be selected so that the opening in the screen is smaller than the particles of the water-bearing material. The total area of the openings should be sufficient to permit a low velocity of flow into the well at the maximum rate of pumping. This velocity should not exceed 1 ft. per minute through the screen openings. Screens are sometimes selected with openings slightly larger than the material to be excluded. The finer particles are

drawn through the well, leaving the larger particles to pack around the outside of the well forming a larger screen for the infiltration of ground water. The largest practicable openings should be selected, as small openings tend to corrode and clog more rapidly than large openings. Sometimes the effect of a large screen with large openings is obtained by packing gravel around the outside of a coarse metal screen which is about the size of the well casing.

18. Deep-well Equipment.—In placing reciprocating pumping equipment in a well the working barrel (see Fig. 13) is connected to the suction pipe, if one is to be used; a length of sucker rod is attached to the working barrel and a length of "drop pipe" is slipped over this and attached to the working barrel. The barrel, sucker rod, and drop pipe are then lowered into the well, successive lengths of sucker rod and drop pipe being attached as the working barrel is lowered. The depth to which the barrel should be lowered is the least practicable depth to prevent dewatering of the working barrel during pumping. This depth can be determined only by test. It bears no relation to the depth of the well.

A recommended type of construction at the top of the well is illustrated in Fig. 5. As in dug and driven wells, care should be taken to secure and to maintain a tight joint so as to avoid pollution of the well water.

19. Cisterns.—A cistern is an underground tank constructed for the purpose of storing rain water which has been caught on a roof or other catchment area. Cisterns are used in localities where other supplies are either unsuitable or unavailable, or where a softer water than the available supply is desired. Care must be taken in the construction of cisterns to make them water tight, not only to prevent the loss of water through leakage, but to prevent the entrance of polluted ground or surface water. The walls of the cistern should be constructed of heavy, substantial masonry. Care should be taken in covering the cistern to make the roof insect proof. Many flying insects, particularly mosquitoes, delight in breeding in such a temperate, moist, and dark place, to the discomfort and possible ill health of nearby dwellers.

The catchment area or house roof should receive occasional attention, particularly with regard to the cleaning off of leaves, birds nests, dead animals, etc. The first rush of rain water on

any catchment area will probably carry with it into the cistern much undesirable material. This can be diverted by the use of a by-pass valve in the leader pipe as shown in Fig. 7. The householder must be alert in the operation of the valve in order to protect the quality of the water in the cistern. Otherwise a rain-water filter should be installed as described in Sec. 104.

The size of the cistern is fixed by the roof or catchment area and upon the number of persons using the water. When all water for all purposes must be supplied from the roof and the annual rainfall is about 40 in., which is well distributed between the seasons, the water supply must be conserved and approximately 500 sq. ft. of catchment area should be available per person. When the rain-water supply is depended upon only for soft water, in addition to some other source of supply, a cistern of 500- to 1,500-gal. capacity should supply the needs of an ordinary family.

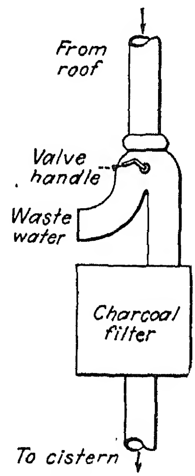


FIG. 7.—By-pass valve and filter in rain-water leader.

20. Springs.—The development of springs and surface streams calls for a knowledge of the principles of underground and surface water which, coupled with the exercise of ingenuity and originality, can often be successful in developing an apparently worthless water supply into one of value or in materially increasing the amount of water available from an existing supply.

The source of all underground water is rain water which has soaked into the ground until it has reached the water already in the ground. The surface of the ground water is called the ground-water table. The ground-water table is not level, but in porous ground it follows approximately the contour of the surface of the ground. Only in limestone regions and in fissured rock are large underground streams encountered.

Springs can be divided into four classes for convenience in considering methods for their development:

1. Overflows of the ground-water table into surface streams. (See Fig. 8.)

2. Underground flows encountering outcropping impervious strata. (See Fig. 9.)

3. Artesian springs. These are underground flows w
are confined for a large area by a superimposed impervious s
tum, the spring water breaking through the stratum near
spring. (See Fig. 10.)

4. Underground streams in fissured rock

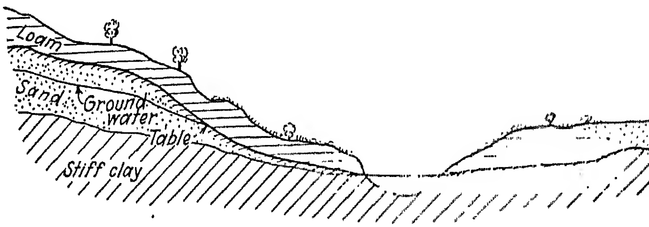


Fig. 8.—Overflow of ground water into surface stream.

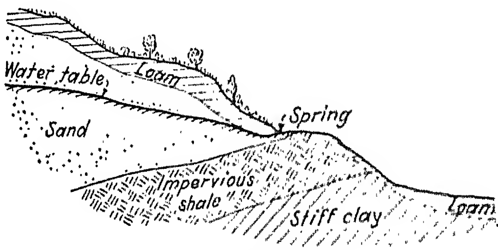


Fig. 9.—A surface spring.

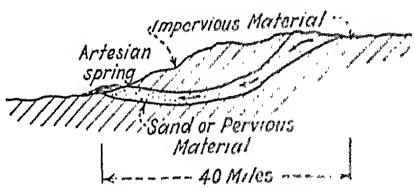


Fig. 10.—Artesian spring.

The first two types of springs are best developed by layi
line of drain tile at right angles to the direction of flow of gr
water, and discharging this into a sunken barrel or other s
which will serve as a pump suction pit or source of supply
desirable arrangement is illustrated in Fig. 11. Springs o
third type can best be developed by the construction of a
well at the site. Little can be done to increase the flow
the fourth type of spring except to clear away the debris

about the mouth of the spring by pick and shovel or by the use of dynamite.

21. Surface Streams.—The development of a surface stream as a source of a private water supply in a populated district is a marked rarity. The quality of the water from a surface stream in an inhabited district is so likely to show pollution as to be unfit for human use without filtration. For summer camps and remote homes a barrel sunk into the stream near the shore or, if adequately protected against floating objects, out in the stream channel, will serve as a satisfactory intake. Care should be taken when sinking the barrel that the water of the stream will

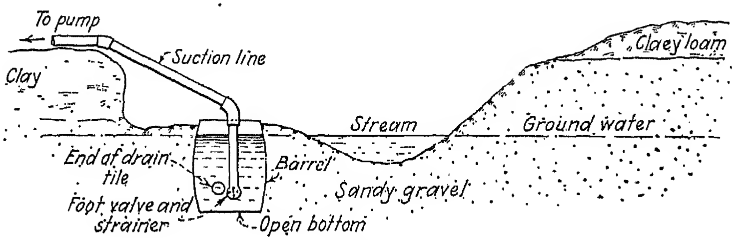


FIG. 11

reach it during the lowest stages of the stream. A well dug in the banks of the stream so that the bottom of the well is about at or slightly below the bottom of the stream should assure water so long as there is flow in the stream. It is to be remembered that the natural direction of flow of underground water is toward a stream and hence a well so located will ordinarily supply ground water of better sanitary quality than the water in the stream.

References

1. "Domestic Engineering," Vol. 101, p. 467, 1920
2. "Water Supply, Plumbing, and Sewerage for the Country Home," *Plumbers Trade Jour.*, Vol. 72, p. 870, 1922.

CHAPTER III

WATER-SUPPLY PUMPS AND STORAGE TANKS

22. Power Used for Small Pumps.—Power for the small pumps used for private water supplies is developed by hand, windmill, hydraulic energy, gasoline, gas, and sometimes hot air. Steam and compressed air are seldom used in very small supplies. Electricity is frequently used for the transmission of power and the operation of pumps

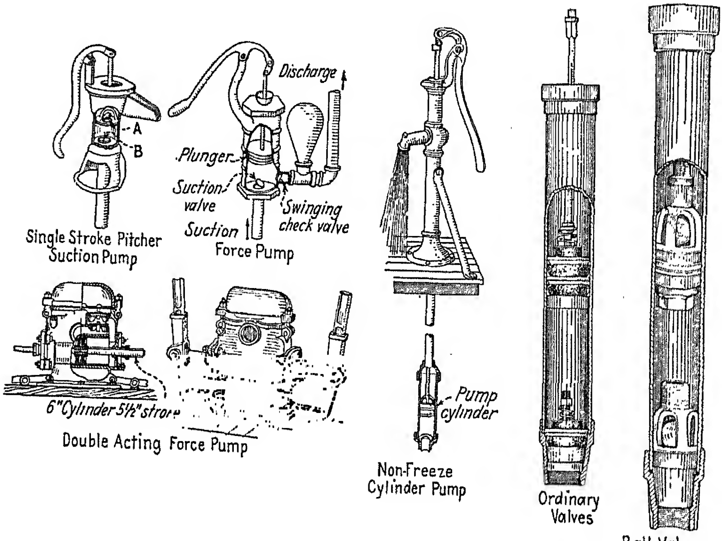


Fig. 12.—Types of hand-operated pumps

23. Hand-operated Pumps.—Some types of hand-operated pumps are illustrated in Fig. 12. The single-stroke pitcher pump operates as follows: When the handle is pressed down the plunger *A* rises; the plunger fits so closely to the walls of the cylinder that a vacuum is created in the chamber below causing the lower valve *B* to open to admit water. The rise of plunger *A* also forces water out of the top of the pump. As plunger *A*

descends, valve *B* closes, preventing the escape of water into the well and leaving the barrel of the pump filled with water some of which will be discharged on the next up-stroke of plunger *A*. The plunger *A* is shown descending in the figure.

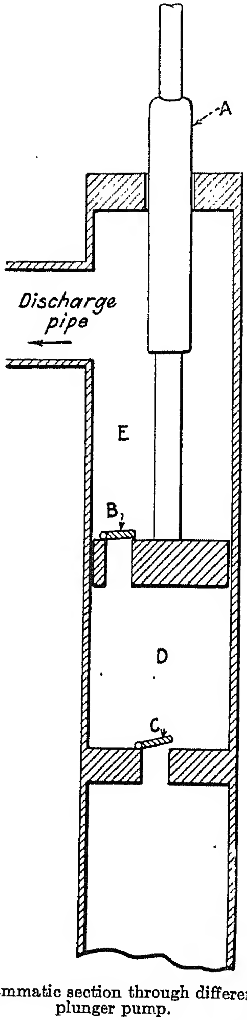
In the maintenance of these pumps difficulty is sometimes caused by the wearing of the packing on the moving plunger, or leakage through the valves, or the catching of some object in the pump so as to hold the valve open. When the packing becomes worn or the valves leak, the pumps will not prime themselves. They can be primed by filling the pump barrel with water so as to cover the moving plunger, or the packing and valves can be repaired so as to make the pumps self-priming. These pumps will seldom lift water by suction to any appreciable height. They should, therefore, be installed with the plunger submerged.

The capacities of hand-operated pumps cannot be expected to exceed 5 gal. per minute under normal operating conditions. Such pumps are used in shallow wells and cisterns.

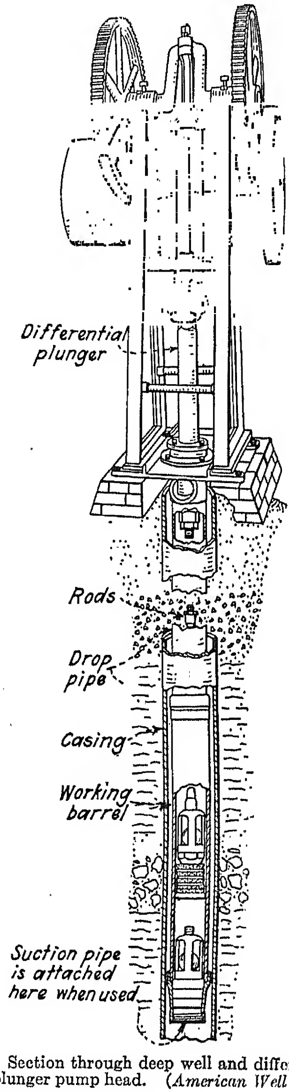
24. Hand- or Power-driven Well Pumps.—The pitcher pump shown in Fig. 12 is known as a single-stroke pump. Water will be delivered only on the up-stroke of the valve. This results in a discontinuous flow of water from the pump. When pumps are power driven greater efficiency can be secured by maintaining a smoother and more continuous flow from the pump by maintaining discharge on both the up- and down-stroke of the valves. This can be accomplished, with more or less success, by the use of (1) an air chamber on the discharge pipe, (2) differential plunger pump, (3) a two-stroke pump, or (4) a pump with a double-acting cylinder. Such devices are more commonly used on power-driven pumps, but are occasionally found on hand-operated pumps.

25. Air Chamber.—An air chamber can be used only on the discharge pipe of a force pump which is discharging water under pressure. Air chambers are most effective on single-acting pumps. When water is being discharged from the pump air is compressed in the chamber. When the discharge valve closes, as on the return stroke of a single-acting pump, or the rate of discharge slackens, the compressed air in the pump expands and discharges the water which had previously entered the chamber, thus aiding in the maintenance of a continuous rate of discharge. The capacity of the air chamber should be about three times the

volume of water discharged on the up-stroke of the pump. The larger the chamber the smoother will be the action of the



Diagrammatic section through differential plunger pump.



Section through deep well and differential plunger pump head. (*American Well Works.*)

FIG. 13.—Differential plunger pump.

pump. Air must occasionally be supplied to the chamber as it is absorbed or carried away by the discharge water. Air can

be admitted to the chamber by draining the water out when the pump is not operating, or a small valve on the suction side of the pump can be opened when the pump is operating. The air admitted in this manner is caught and retained in the air chamber.

26. Differential Plunger Pump.—A differential plunger pump is shown in Fig. 13. In its operation water is discharged on both the up- and down-strokes of the pump, but it is sucked in only on the up-stroke. It operates as follows: As the differential plunger *A* and the valve *B* move upwards water is drawn into chamber *D* through valve *C*. Valve *B* is closed and some of the water in chamber *E* is discharged from the pump. It is not all discharged because some must remain to fill the space previously occupied by plunger *A*. On the down-stroke valve *C* is closed and there is no intake of water. The water in chamber *D* passes through valve *B* into chamber *E* from which a portion of it is forced by the entering plunger *A*. For smooth operation the size of the differential plunger should be such that the amount of work on both strokes is equal.

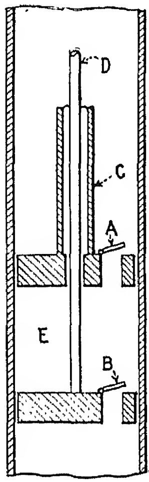


FIG. 14.—Diagrammatic section through two-stroke pump cylinder.

27. Two-stroke Pump.—A two-stroke pump is illustrated in Fig. 14. It consists of two single-stroke pumps, one within the other, with independent rods. It operates as follows: Pump rod *D* is solid and moves within the hollow rod *C*. The rods *C* and *D* move in opposite directions, one moving down as the other moves up. As *D* moves up valve *B* is closed and the water in chamber *E* is discharged through valve *A*, one-half of it being discharged from the pump. As rod *C* moves up the water which has previously passed through valve *A* is discharged from the pump and the chamber *E* is refilled through valve *B*.

28. Double-acting Cylinder Pump.—A section through a double-acting cylinder pump is shown in Fig. 15. *A* and *C* represent fixed partitions across the working barrel. *F* and *H* are check valves in these partitions. *B* is a moving partition, or plunger, attached to the pump rod *D*. *E* and *G* are check valves over the channels passing through the pump rod. On the down-stroke *F* and *H* are closed; *E* and *G* are open. Water is being drawn into the pump through *J* and is being discharged

through *E*. On the up-stroke *E* and *G* are closed; *F* and *H* are open. Water is being drawn into the pump through *H* and is being discharged at *F*. A disadvantage of the double-acting pump is evident when long rods are used. The thrust of the downstroke tends to bend the rods against the sides of the well. It has an advantage over the two-stroke pump, however, in

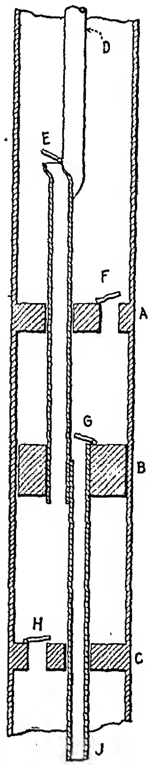


Fig. 15A.—Diagrammatic section through a double acting deep well pump cylinder.

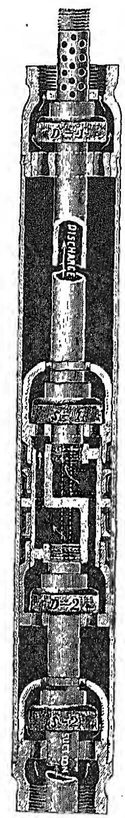


Fig. 15B.—Section through double acting pump cylinder. (*Scott Valve Company.*)

that water is both taken in and discharged on both strokes of the pump.

29. Windmills.—Windmills are used for operating such pumps as are described in the preceding sections. The power for operating the mill is derived from the deflection of the direc-

TABLE 5.—CAPACITIES OF WINDMILLS, GALLONS PER MINUTE
(U. S. Wind Engine and Pump Company)

Diameter of mill wheel, feet	Velocity of wind miles per hour	Revolutions of wheel per minute	Elevation, feet raised						Useful horse-power developed
			25	50	75	100	150	200	
8½	16	70 to 75	6.2	3.0	....	....	....	....	0.04
10	16	60 to 65	19.2	9.6	6.6	4.8	....	....	0.12
12	16	55 to 60	34.0	18.0	11.9	8.4	5.7	....	0.21
14	16	50 to 55	45.1	22.6	15.3	11.2	7.8	5.0	0.28
16	16	45 to 50	64.6	31.7	19.5	16.2	9.8	8.1	0.41
18	16	40 to 45	97.7	52.2	32.5	24.4	17.5	12.2	0.61
20	16	35 to 40	125.0	63.8	40.8	31.2	19.3	16.0	0.78
25	16	30 to 35	212.4	107.0	71.6	49.7	37.3	26.7	1.34

TABLE 6.—PRESSURE OF WIND AGAINST PLANE SURFACES. ACTION ON WINDMILLS

Velocity of wind, miles per hour	Pressure, pounds per square inch[1]	Description of wind	Effect on windmill
3	0.027	Calm	Will not move
8	0.19	Light air	Just starts
13	0.5	Light breeze	Pumps well
15	0.67		Rated breeze
18	1.08	Gentle breeze	Excellent work
23	1.75	Moderate breeze	Excellent work
28	2.6	Fresh breeze	Maximum results
34	3.9	Strong breeze	Too fast, should be folded back out of service
40	5.3	Moderate gale	
48	7.7	Fresh gale	
56	10.4	Strong gale	
65	14.0	Whole gale	
75	18.8	Storm	
90	27	Hurricane (tornado)	Wrecked

[1] $P = 0.0032\ V^2$.

tion of the wind when it strikes the vane of the wheel, the force of the deflection causing the vane to move. The motion of the vane is transmitted to the pump by means of a train of gears and reciprocating parts. The speed of revolution of the wind wheel, the diameter of the wind wheel, the pitch of the vanes, the ratio of the gears, and the speed of the pump must all be proportioned by the designer for the conditions under which the pump is to operate. The loading of the windmill should be proportioned to the average wind velocity in the locality. The valves, plungers, bearings, and gear wheels are the wearing portions which require attention and repairs. Well-lubricated bearings and moving parts will reduce needed repairs and will aid in maintaining the rated capacity of the pump. The capacities of windmills are given in Table 5 and the wind pressures at various velocities in Table 6.

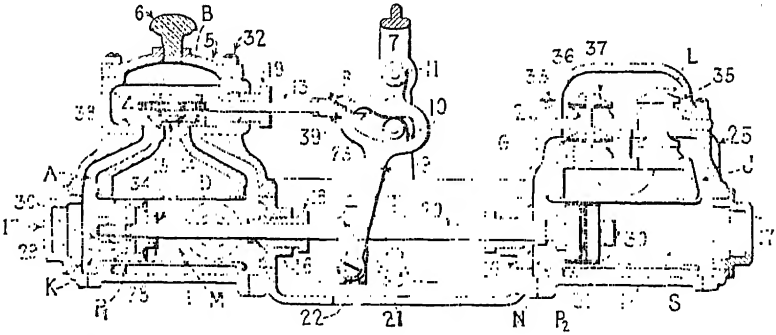
TABLE 7.—CAPACITIES OF RIDER-ERICSSON HOT-AIR PUMPING ENGINES

Diameter of cylinder, inches	Rider engines						Ericsson engines				
	Water discharged, g.p.m.	Suction and discharge pipes, inches	Gallons of water pumped			R.p.m.	Water discharge, g.p.m.	Suction and discharge pipes, inches	Gallons of water pumped		
			Per cubic foot of gas	Per gallon of kerosene	Per pound of hard coal				Per cubic foot of gas	Per gallon of kerosene	Per pound of hard coal
5	60	1	18	750	110	120 to 160	25	3/4	12 1/2	600	37 1/2
6	165	1 1/2	14	1,333	200 to 250	100 to 120	50	1	18 3/4	600	75
8	330	2	22 1/2	2,000	280 to 330	100 to 120	83	1 1/4	22	1,000	100
10	600	2 1/2	36	4,300	440 to 500	80 to 110	167	1 1/2	35	1,333	167

Gasoline or electric motors are sometimes connected to windmill driven pumps to supplement the wind on calm days. The gasoline engine or the electric motor should have a rated capacity of about 1/10 hp. for every 10 ft. of lift of water, the lift representing the total height from the surface of the water in the well to the discharge valve.

30. Hot-air Engines.—Hot-air engines for driving pumps are adapted to cold climates and to localities where fuel is cheap and no other type of motor can be used with ease. They are seldom used in populous districts. Engines are available with capacities between 150 and 2,800 gal. per hour, with a lift not greater than 50 to 75 ft. The variations in duty are indicated in Table 7.

31. Hydraulically and Pneumatically Driven Pumps.—Hydraulically driven pumps are used where two water supplies are available, one of relatively poor quality at a high pressure and the other of good quality at a relatively low pressure. This condition exists in localities where the public water supply is hard in quality and it is desired to raise soft rain water from cisterns to roof or attic tanks. The pump is driven by the hard public water supply. The hard water used for driving the pump may



No.	Name of Piece	No.	Name of Piece	No.	Name of Piece
1.	Cylinders, brass-lined	15.	Slide valve	27.	Bracket
2.	Pump-valve plate	16.	Inside cylinder head	28.	Inside piston follower
3.	Pump-valve cap	17.	Outside cylinder head	29.	Outside piston follower
4.	Engine-valve chest	18.	Piston-rod stuffing-box nut	30.	Piston-rod nut
5.	Engine-valve chest cover	19.	Valve-rod stuffing-box nut	31.	Piston-cup leather.
6.	Oil plug	20.	Piston rod	32.	Screw for engine-valve chest
7.	Rock-shaft arch	21.	Cross-head	33.	Screw for pump-valve cover
8.	Valve-rod jaw	22.	Shoulder screw for cross-head	34.	Cushion (rubber)
9.	Rock shaft (long lever)	23.	Valve-rod link	35.	Pump-valve leather
10.	Rock shaft (short lever)	24.	Drain cock	36.	Pump-valve seat
11.	Rock-shaft arbor	26.	Drip pan	37.	Pump valve complete
12.	Rock-shaft arbor screw			38.	Slide-valve seat
13.	Valve rod			39.	Screw for valve-rod link
14.	Valve-rod nut				

FIG. 16.—Section through a hydraulically driven duplex pump. (*The Geo. N. Roberts Co.*)

be run to waste or it may be made available, at a much reduced pressure after it has passed through the pump, for flushing fixtures, cooking, or other purposes.

A section through one of these pumps is shown in Fig. 16. In the figure high-pressure water is entering the pump through pipe A; pistons P_1 and P_2 are moving to the right; and soft or pure water is being discharged from pipe J. The slide valve is open at A to admit water to chamber K, and the valve at B is open so as to waste water from chamber M at the same time preventing its escape from chamber K. The poorer quality of

water is wasting through D. The valve at G is open so as to admit water of good quality to chamber N. The valve at L is open so as to permit water to escape from chamber S. When the stroke is completed the position of the valves is reversed by a mechanism attached to the moving piston rod and the pistons move to the left drawing water into chambers M and S, discharging it from chamber N, and wasting it from chamber K.

The pressure and volume of water required to operate such pumps depend on the height and quantity of water which is to be lifted. Under ordinary conditions the efficiencies of these pumps cannot be expected to exceed 50 per cent, and the areas of the pistons and the stroke of the pump should be designed to fit the conditions to be met in service.

Pneumatically driven pumps operate on the same principle as the hydraulically driven pumps, compressed air being used instead of water to actuate the pump. Such pumps are seldom used for household supplies as they are suitable only where compressed air is available at a low cost for the transmission of power.

32. Power-driven Pumps.—Power-driven pumps, or, as they are more commonly known, power pumps, are driven by gasoline engines, electric motors, or some less-frequently used motive power. They are connected to the motor by means of belt, gears, or shafting. Belt connection makes possible ease in the adaptation of motors and pumps of diverse speeds but the space occupied is greater than for other forms of connection. Gears assure positive operation of the pump but they are sometimes noisy, require constant lubrication, and are so inflexible that a sudden stoppage in the discharge pipe will result in rupture of some part of the pipe or mechanism. Direct-connected pumps and motors on the same shaft give the most efficient driving mechanism between the pump and motor but they necessitate the use of a pump and motor of the same speed.

The most common type of power pump is the triplex pump illustrated in Fig. 17. It consists of three reciprocating single-acting water cylinders. Such pumps have a long life, will give excellent service, are suitable for varying loads without material variations in efficiency, and are self-priming. They are noisy and require attention and lubrication. They must be secured to a firm foundation and care should be taken in the location of the suction pipe to avoid bends, sags, and air pockets. The discharge

pipe should be equipped with a gate valve and a check valve, the latter being nearer to the pump. The mechanical efficiency of belt-connected triplex power pumps is about 65 to 75 per cent, the efficiency of the belt alone being about 95 to 97 per cent. The efficiency of geared connections is about 87 to 93 per cent.

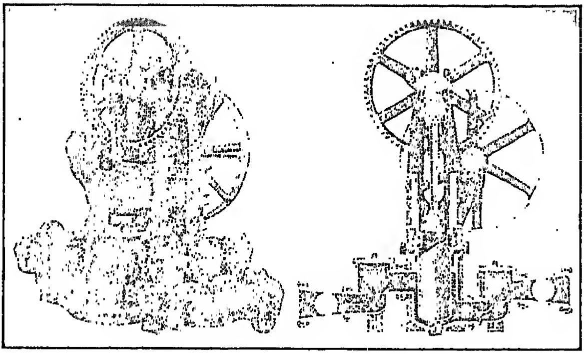


FIG. 17.—Rumsey triplex power pump.

33. Hydraulic Rams.[1]—Hydraulic rams are pumps which are actuated by water power. They may be used for raising flowing water to a height greater than its own level, or water of unsatis-

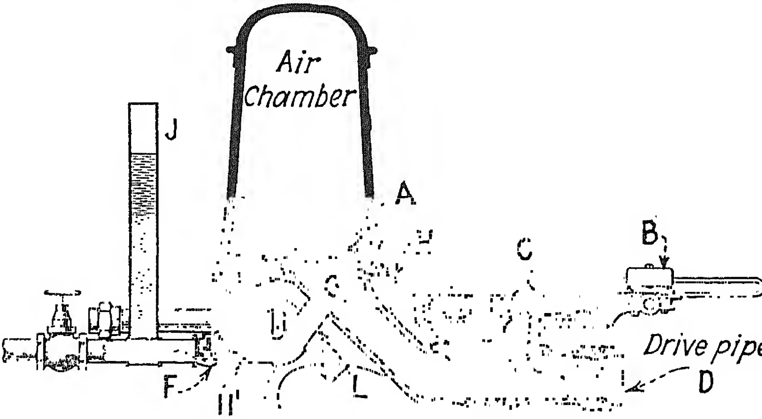


FIG. 18.—Rife double-acting hydraulic ram.

factory quality can be used to raise water of a satisfactory quality from a nearby spring to any reasonable elevation desired. A hydraulic ram is illustrated in Fig. 18. Where the ram raises only its own water supply, pipe L and everything to the left of it

do not exist. Under these conditions it operates as follows: Water enters the ram through the drive pipe and wastes out of the ram through the valve C. The water gains such velocity that valve C is suddenly slammed shut by the flowing water. The sudden closing of the valve creates sufficient pressure through water hammer to force valve A open, thus discharging a small quantity of water through the discharge valve A. The air chamber on the discharge pipe prevents the development of a high pressure in the discharge pipe and reduces the fluctuations in the rate of discharge. After the pressure impulse resulting from the closing of the valve C has been expended there is a tendency for the water to surge backward up the drive pipe. This surge opens a small air valve H, and admits a small quantity of air which is required to replenish the air in the air chamber. The surge, with the aid of weight B, also serves to open valve C. Valve A is automatically closed by the pressure of the water in the discharge pipe. The cycle of action is repeated indefinitely.

When pipe L is connected as shown in Fig. 18, the ram will pump one quality of water by means of another quality of water. The pure water at H comes from a source at least 18 in. higher than the less pure supply at D. When valve C is open impure water is wasting from it and pure water is flowing through the check valve at F into the drive chamber at G and is also wasting through valve C. When valve C slams shut valve F is also shut and pure water passes through the valve at A. There is thus a slight waste of pure water through valve C but no impure water passes through valve A.

In the selection of a hydraulic ram the information which must be obtained includes: (*a*) the rate of flow of water during various seasons of the year, (*b*) the demand for water during the corresponding periods, (*c*) the available fall of the water for driving the ram, (*d*) the height of the desired lift, and (*e*) the greatest possible length of drive line. The length and diameter of the drive pipe are important because upon them depends the success of the ram. The lower the available driving head the longer and larger must the drive pipe be. In general, the length of the drive pipe is about seven times its fall; it may vary between five and ten times, depending upon the conditions of delivery. The diameter of the drive pipe is usually about twice the diameter of the delivery pipe. Some data on hydraulic rams are given in Table 8. The design of hydraulic rams requires special knowledge and experi-

Table 8.—Sizes and Capacities of Hydraulic Rams[1]

Rife Engine Company					Markey Machinery Company				
Number	Drive pipe, inches	Delivery pipe, inches	G.p.m. to operate	Least permissible fall, feet	Number	Drive pipe, inches	Delivery pipe, inches	Minimum g.p.m. to operate	Maximum discharge, g.p.m.
10	1¼	¾	2 to 6	2	1	1	½	4	1/16 to 1
15	1½	¾	6 to 12	2	1½	1½	¾	8	⅛ to 2
20	2	1	8 to 18	2	2	2	1	15	¼ to 5
25	2½	1	12 to 28	2	3	3	1½	25	⅝ to 16
30	3	1¼	20 to 40	2	4	4	2	45	1 to 35
40	4	2	30 to 75	2	6	6	3	90	3 to 65
80	8	4	150 to 300	....	9	9	4	200	7 to 140
120	12	5	375 to 700	....	12	12	5	300	13½ to 450
...	....	....	....	....	18	18	8	600	22½ to 900
...	....	....	....	....	24	24	10	1,000	450 to 1,600

[1] From information given in catalogue.

ence with them. It should not be attempted by an inexperience person. In general, rams will operate with a minimum drop of ft. in the drive pipe and with a minimum drive supply of 3 ga per minute.

The ratio of water delivered to water wasted depends on th fall and size of the drive pipe and the height of the lift. Th best performances have shown an efficiency of 90 per cent The efficiencies to be expected under normal conditions are show in Table 9. The quantity which will be delivered can b computed from the expression

$$Q_1 = E\,\frac{Q_2 \times H_2}{H_1},$$

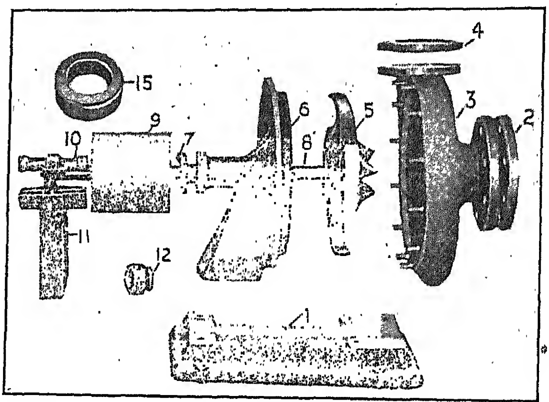
in which

Q_1 = the rate of delivery of the water from the discharge pipe
Q_2 = the rate of flow in the drive pipe (in the same units as Q_1)
H_1 = the total lift in the discharge pipe.
H_2 = the net head (approximately the height of fall in the driv pipe) available (in the same units as H_1).
E = the efficiency of operation (see Table 9).

Table 9.—Efficiencies of Rife Hydraulic Rams

Ratio of discharge lift to driving head..........	2½	3	18	23	30
Efficiency, per cent..........................	75	70	67	60	50

34. Centrifugal Pumps.—Centrifugal pumps are well suited to use for small water supplies, as well as for large supplies, because of the simplicity of their parts, the simplicity of their operation, and their "fool-proof" qualities. The simplicity of the parts of a centrifugal pump is illustrated in Fig. 19. In operation the water enters the pump casing at the center, point 2 in the figure, where it encounters some rapidly revolving vanes on the runner. The velocity of the water is greatly increased as it starts to travel around with the vanes. The centrifugal force thus brought into action forces the water rapidly and with an increasing velocity to



1. Base
2. Suction companion flange
3. Volute with studs
4. Discharge companion flange
5. Runner
6. Cover
7. Gland
8. Shaft
9. Pulley
10. Box cap
11. Bracket box
12. Set collar for type *A* or *B*
15. Horizontal ball bearing

Fig. 19.—Parts of a centrifugal pump. (*American Well Works.*)

the periphery (outer edge) of the revolving vanes, called impeller blades. Here the velocity of the water is reduced in the discharge channels and the velocity energy is changed to pressure. The blades of the impeller do not push the water out of the pump as the blades of a paddle wheel push a boat along. The design of centrifugal pumps requires special knowledge of hydraulics, mechanics, and the actions which take place in the pumps. The limitations and operations of the pumps should be understood, however, in order that the proper pump may be selected for any particular service.

There are two types of centrifugal pumps: one is known as a volute pump and the other as a turbine pump. In a volute pump

the water leaving the impeller is discharged into a volute or snail-shell-shaped casing the cross-sectional area of which increases directly as the increase in the quantity of water flowing through it, thus maintaining a constant velocity of discharge. In a turbine pump the casing of the pump is circular in shape and the impeller is surrounded by diffuser ribs forming water passages which gradually enlarge, slowing down the velocity and converting velocity energy into pressure. The volute pump is simpler, less expensive, and better suited for small sizes. The turbine pump is more efficient and is found more often among the larger centrifugal pumps.

There is no practicable limit to the capacity or pressure which can be obtained in centrifugal pumps. As the pressures increase the speed of revolution or the size of the impeller, or both, may increase; or the number of impellers may be increased, the impellers being so arranged that the discharge from one enters the suction of the other. Pumps with two or more impellers, one discharging into the other, are known as multi-stage pumps. The exact dimensions, speed of revolution, etc., of a pump for any particular service is fixed by the manufacturer. No simple rule is available by which the purchaser can determine the probable performance of a pump from its measurements. The capacity can be approximated by assuming that the velocity in the discharge pipe is 10 ft. per second and multiplying this velocity by the cross-sectional area of the discharge pipe.

The efficiencies of centrifugal pumps in domestic water supply service is relatively low, as is indicated in Table 10. Unfortunately, even such low efficiencies are not attained unless the

TABLE 10.—SIZES, CAPACITIES, AND EFFICIENCIES OF CENTRIFUGAL PUMPS

Size of pump, inches	Capacity g.p.m.		Efficiency
	10-ft. velocity	12-ft. velocity	
1	25	...	27
1½	55	...	35
2	98	...	43
3	220	264	50
4	392	470	55
5	612	734	59
6	881	1,058	62
8	1,567	1,880	65
10	2,448	2,938	67
12	3,525	4,230	69

pump is designed for the particular service to which it is to be put. The efficiency of a centrifugal pump will vary materially with the rate of discharge, the pressure, and the speed of revolu-

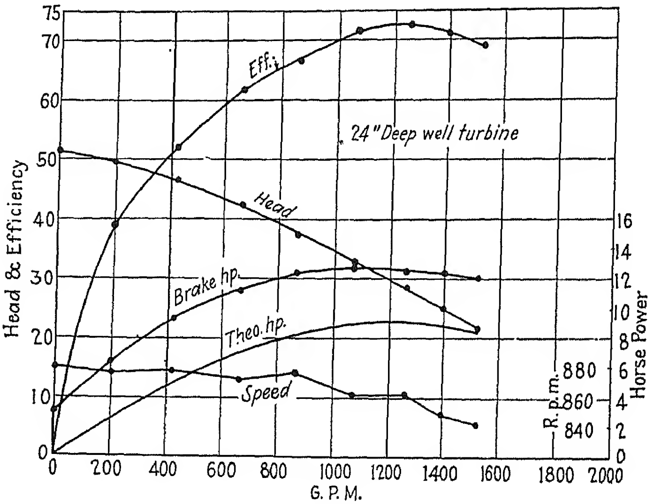


FIG. 20.—Characteristics of a centrifugal pump. (*American Well Works.*)

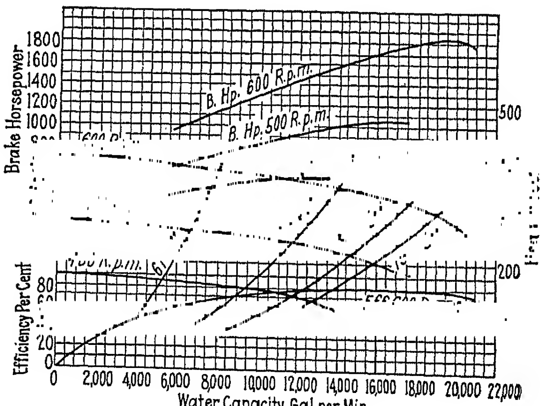


FIG. 21.—Characteristics of De Laval centrifugal pump at different speeds.

tion. The relation between these factors for a 24-in. deep-well turbine pump is shown in Figs. 20 and 21. These relations are known as the characteristics of the pump. The most desirable pump, from the point of view of efficiency, to select for any partic-

ular service, is a pump in which the characteristics show the efficiency remaining approximately constant under the normal variations of operation. If economy of operation is to be considered the characteristics of the pump should be determined by test before purchase, or should be specified in the purchase agreement and later subjected to test. Such conditions are seldom enforced in the purchase of small pumps, the reputation of the manufacturer and his guarantee being relied upon without further test.

The material of the pump can be investigated by the purchaser before purchase. Standard-fitted centrifugal pumps are equipped with a cast-iron casing, steel shaft, bronze shaft sleeves (if any), a cast-iron impeller, and cast-iron diffusion vanes (if any).[2] Such pumps are suitable for ordinary service when moving non-corrosive liquids. Pumps handling sewage or corrosive liquids should be bronze fitted or all bronze or should be made of special composition to resist the effect of the particular liquid pumped. Bronze-fitted pumps have a cast-iron casing, steel shaft, bronze shaft sleeves, bronze impeller, and bronze diffusion vanes (if any). All bronze pumps have all parts, which are in contact with the liquid, made of bronze except that a bronze-covered steel shaft or a monel metal shaft may be used.

Centrifugal pumps are classed as high-speed machines. The smaller sizes are, therefore, usually driven by electric motors, either belt, gear, or directly connected to the pump. Gasoline or steam engines are less frequently used. Where the electric motor and the pump are on the same shaft the speed of the motor and the pump must be the same, and a flexible connection must exist in the shaft between the motor and the pump. This connection will allow for only a slight eccentricity due to improper alignment of the shaft. Where the pump and motor are connected by a belt or gear train the two machines need not have the same speed the gear ratio or the diameter of the pulleys being relied upon to adjust the speeds of the pump and motor. For example, if the speed of the pump is 690 r.p.m. and that of the motor is 1,140 r.p.m. the diameters of the pulleys should be in the ratio of 1,140 ÷ 690 = 1.65, the larger pulley being on the slower-moving machine. That is, a 3-in. pulley on the motor will call for a 5-in. pulley on the pump under the above conditions. The Hydraulic Society[2] recommends that electric motors under 100 hp., rated on a 50° F. basis, have an extra margin of capacity

of at least 20 per cent above the horsepower required by the pump. This recommendation is made to eliminate the chances of trouble from overheated motors as a result of possible deterioration, variation in operating conditions, location in overheated places, etc.

Troubles resulting from the setting of a centrifugal pump can best be avoided by bolting the pump down to a firm concrete foundation and arranging the suction pipe as short and as straight as possible. The discharge pipe should be equipped with a check valve and a gate valve, the former being nearer to the pump. If any suction lift is required the suction pipe should be equipped with a foot valve and provision should be made for priming the pump. This can be done in any of three ways: (1) by a by-pass around the gate valve which will admit water from the discharge pipe into the pump, (2) by an independent supply from some other source than the pump, and (3) by the

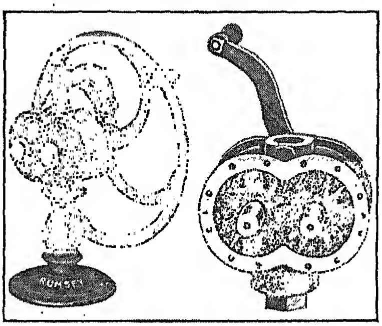


FIG. 22.—Rotary pump. (*Courtesy Rumsey Pump Co.*)

operation of a steam ejector or other vacuum pump on the suction line. Centrifugal pumps are often set so that there is no suction lift. This can be done by placing the pump below the source of supply or by immersing the pump in the water. The latter situation is not recommended, as care and lubrication of the pump are likely to be neglected.

35. Rotary Pumps.—Rotary pumps resemble centrifugal pumps in outward appearance, in operation, in the manner of their setting, and in the motors used to drive them. In principle of operation they differ materially, however, from centrifugal pumps as they are distinctly displacement pumps, *i.e.*, the blades of the rotor push the water through the pump. A cut through a rotary

pump is shown in Fig. 22. The blades of the rotor fit tightly together and to the casing. As the blades revolve water is displaced from the pump casing and is pushed through the discharge pipe. A high vacuum is created because of the tight-fitting moving parts.

Rotary pumps have about the same efficiencies as centrifugal pumps in the smaller sizes but lower efficiencies than large-size centrifugal pumps. Although rotary pumps have no valves, the close fit of the rotor blades make them suited only to the pumping of liquids free from suspended solids. They are less fool-proof than centrifugal pumps because the closing of the discharge valve while the pump is in operation will result in damage to some part of the pumping equipment. Rotary pumps are self-priming and no foot valve is required on the suction line. The same care in the setting of the pump is required as in the setting of a centrifugal pump and a check and gate valve should be placed on the discharge line.

The available market sizes and other data on rotary pumps are given in Table 11.

TABLE 11.—DATA ON ROTARY PUMPS

Blackmer rotary pumps[1]												Roots' small-capacity rotary pumps[2]				
Pump number	Pipe sizes, inches	R.p.m.	Capacity, g.p.m.	Suction lift, feet	Maximum pressure, pounds square inch	Pump number	Pipe sizes, inches	R.p.m.	Capacity, g.p.m.	Suction lift, feet	Maximum pressure, pounds square inch	Displacement per revolution, gallons	R.p.m.	Gross g.p.m.	Horsepower[3] at maximum g.p.m.	Suction and discharge pipes, inches
0	½	600	6	3	75	6	2½	250	100	15	100	0.06	750	45	0.3	1¼
1	¾	500	12	10	75	8	3½	200	200	18	100	0.10	600	60	0.4	1¼
2	1	500	20	10	75	10	5	175	350	20	75	0.175	475	83	0.6	1½
3	1½	400	35	12	75	12	6	150	500	20	75	0.25	450	112	0.8	2
4	2	400	50	12	100	6 spe.	2	250	100	15	40	0.50	400	200	1.3	3
												0.95	340	320	2.1	4

[1] From catalogue of Blackmer Rotary Pump Company, Petroskey, Mich.
[2] From catalogue of P. H. and F. M. Roots Company, Connersville, Ind.
[3] Based on 25-ft. discharge head.

36. Air-lift Pumps.—Air-lift pumps are used principally in well pumping. They have the advantage over all other types of well pumps in the simplicity of their parts and in that there are no moving parts in the well. They are able to discharge more water from a well of small size than any other type of pump,

provided the water is available in the ground. They give long service, low maintenance cost, and great reliability. Their efficiency is low, however, and they usually necessitate digging the well deeper than would otherwise be required because of the necessary submergence of the end of the air pipe, known as the foot piece. If the water must be raised to an appreciable height above the ground surface, additional pumping equipment is desirable at the surface as the air lift is not suitable to the dis-

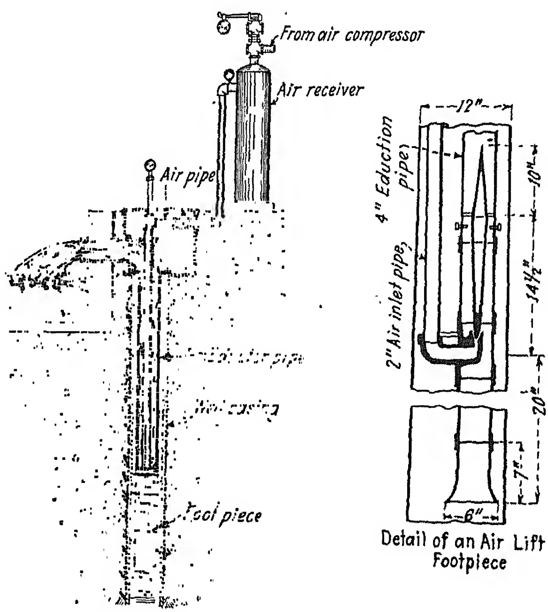


FIG. 23.—Air lift installation and details of footpiece. (*Eng. News-Record*, Vol. 82; p. 1112, 1919.)

charge of water under high pressure. The aeration of the water may increase its corrosiveness or it may be advantageous by precipitating dissolved minerals, such as iron, from the water. The efficiencies of air lifts are in the neighborhood of 25 to 33 per cent, the higher efficiencies being secured at the lower lifts.

The use of an air lift should be limited to conditions where efficiency can be sacrificed for the sake of reduction in maintenance expense or it is desired to increase the output of a well, greater reliability is desired than would be obtained through some other available equipment, or where the well is too crooked

to permit of the use of rods or shafting in the well, or the wate must be lifted more than about 200 ft. in the well.[3,4]

A section through an air lift in a well is shown in Fig. 23 Compressed air enters the bottom of the discharge or educto pipe through a diffuser apparatus called the foot piece. Th water is partly blown out of the well by the rising air bubble acting as pistons and is partly lifted from the well because th weight of the column of air and water is balanced by the weigh of the solid column of water outside of the well. In order t lift the water from the well there must, therefore, be a consider able height of water outside of the well or, in other words, th foot piece must be deeply submerged. The ratio of the dept of the water D, outside the well, to the total lift, $D + H$, i called the ratio of submergence, or more frequently the sub mergence. It should be measured when the pump is in operatio as it will differ from conditions when the pump is idle. Th actual level of the water in a well during operation cannot b predicted with accuracy. The lift and required submergenc are assumed and adjustments are made after the well has bee tested. The ratio $D/D + H$, as recommended by the Sulliva Machinery Company, is given in Table 12.

TABLE 12.—SUBMERGENCE OF AIR LIFT PUMPS
(Sullivan Machinery Company)

Lift, feet	Submergence, per cent	Lift, feet	Submergence, per cent	Lift, feet	Submergence, per cent
Up to 50	70 to 66	100 to 200	55 to 50	300 to 400	43 to 40
50 to 100	66 to 55	200 to 300	50 to 43	400 to 500	40 to 33

The sizes of the parts of the Pohle air lift are given in Table 13 Data, furnished by the American Steam Pump Company, o air consumption by air lifts is given in Table 14. The equip ment of an air lift includes an air compressor, an air receiver fo storing compressed air to make the operation of the compresso and air-lift smoother, the necessary air piping, and a foot piec to distribute the air in small bubbles at the bottom of the educto pipe. By the addition of a "booster" on the upper end of th eductor pipe the air is separated from the water and the pressur of the air and the kinetic energy of the high velocity of the wate

TABLE 13.—POHLE SIDE-INLET AIR LIFT, CAPACITIES AND PIPE SIZES

Air pipe, inches	Water pipe, inches	Size of well, inches	G.p.m. capacity[1]	Approximate cubic feet of free air per minute — Lift, feet 50	100	200	Air pipe, inches	Water pipe, inches	Size of well, inches	Capacity g.p.m.[1]	Approximate cubic feet of free air per minute — Lift, feet 50	100	200
½	1	3	7	2.3	4.5	7.7	1½	3½	7	120	39	78	132
¾	1½	4	20	6.5	13	22	1½	4	8	160	52	104	177
1	2	4½	35	11	23	29	1½	5	9	250	81	162	276
1	2½	5	60	20	39	66	2	6	10	350	114	226	386
1¼	3	6	90	29	58	99							

[1] Maximum for ordinary lifts.

TABLE 14.—APPROXIMATE AMOUNT OF FREE AIR REQUIRED TO ELEVATE WATER BY AIR LIFT

(Based on submergence of 60 per cent. American Steam Pump Company)

Lift, feet	20	30	40	50	60	80	100	120	140	160	180	200	250
Air pressure, pounds, square inch	13.5	20	27	34	40.5	54	67.5	81	94.5	108	121.5	135	168
Cubic feet free air per g.p.m.	0.310	0.350	0.387	0.422	0.457	0.522	0.585	0.642	0.697	0.755	0.810	0.862	0.988

issuing from the well are converted into pressure to raise the water to a higher elevation. The compressed air is released from the booster through a valve, which is throttled by trial, to obtain the best operating conditions.

37. Hydropneumatic Pumping Equipment.—A combination of an automatically operated electric motor and a small pneumatic pressure tank, such as is used for household equipment, is illustrated in Fig. 24. The types and sizes of electrical equipment available for operating these devices are listed in Table 15. Where electricity is not available gasoline motors can be installed but the advantage of automatic operation is lost, and larger pneumatic storage tanks must be used.

When the pump is not operating, the expansion of the air in the pneumatic tank is sufficient to raise the water to the desired height. When the air pressure is so reduced as no longer to discharge the water or to cut down the flow materially, the electric motor is automatically put into operation thus restoring the water pressure. The opening of a faucet anywhere in the plumbing system of the building will reduce the pressure in the

pneumatic tank so as to throw the motor into operation and force water directly into the piping system. The pumps on such devices operate on either the reciprocating, centrifugal, or rotary (displacement) principle. Most of such devices on the market are patented and can be obtained directly from the dealers. They are very satisfactory and give good service.

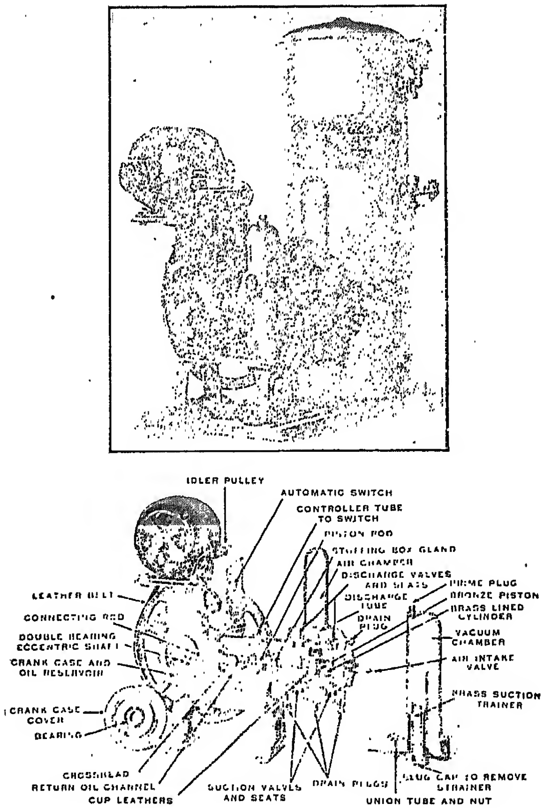


FIG. 24.—Electric-pneumatic pumping system. (*The Deming Co.*)

Units are available in practically all capacities from one gallon up to 400 gal. per minute.

The capacity of the pneumatic tank should not be less than 30 gal. for a five-fixture installation. The capacity should be increased in proportion to the additional fixtures but beyond 70 gal. the capacity of the tank need not be increased for household

supplies. In any installation, the pump should not be thrown on and off more often than about once in 15 to 30 min. The pneumatic tank should, therefore, have a storage capacity equal to approximately 30-min. use, or thirty times the amount of water thrown by the pump in 1 min. The subject of pneumatic storage tanks is more fully discussed in Sec. 42.

TABLE 15.—ELECTRICAL EQUIPMENT FOR PNEUMATIC PUMPING
(Recommendations of Paul Pump Company)

		Transformer to motor, 200 ft. or less				Transformer to motor, 100 ft. or less				Plant to motor, 100 ft.
Motor, horsepower	Voltage / Cycles / Phase	110 / 60 / 1	220 / 60 / 1	110 d.c.	220 d.c.	110 / 60 / 1	220 / 60 / 1	110 d.c.	220 d.c.	32 d.c.
1/8	Wire gage	14	14	14	14	14	14	14	14	9
	Fuse, amperes	5	5	5	5	5	5	5	5	15
1/6 to 1/4	Wire gage	12	14	12	14	14	14	14	14	7
	Fuse, amperes	10	5	10	5	10	5	10	5	20
1/2	Wire gage	9	10	9	10	12	14	12	14	3
	Fuse, amperes	15	10	15	10	15	10	15	10	60
1	Wire gage	6	9	6	9	9	12	9	12	
	Fuse, amperes	30	20	30	20	30	20	30	20	
2	Wire gage	3	6	3	6	6	9	6	9	
	Fuse, amperes	60	30	60	30	60	30	60	30	

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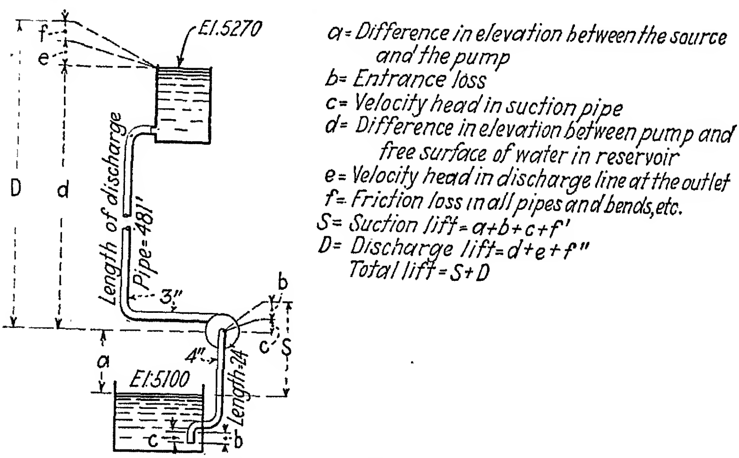


FIG. 25.—Suction and discharge lifts of a pump.

38. Computation of Suction and Discharge Lift.—In selecting the capacity and in determining the location of a pump the suction

and discharge lifts are important considerations. This information should be furnished by the purchaser to the pump manufacturer. The total lift, discharge head plus suction lift, includes the difference in elevation between the free surfaces of the water at the source and at the point of discharge; all losses of head due to friction, entrance, etc.; and the velocity head in the suction pipe and the discharge pipe. The suction lift, discharge head, and total head are illustrated in Fig. 25. One velocity head is equal to $V^2/64.4$ in which V is the velocity of flow in feet per second.

The entrance loss for a pipe flush to the face of a wall, as shown in Fig. 26A, is assumed to be one-half a velocity head. If the suction pipe protrudes into the reservoir, as shown in Fig. 26B, the loss is one full velocity head, and if the pipe is arranged as in Fig. 26C some amount between one-half and one full velocity head is assumed. The friction loss in pipes and bends can be computed from the information given in Tables 16, 17, 18, 19, 20, 21, and 22.

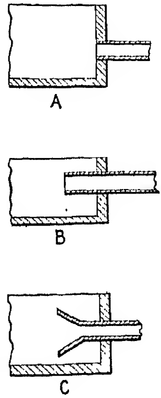


FIG. 26.—Pipes in reservoirs.

Example.—Let it be required to determine the total lift for the pump shown in Fig. 25 when the rate of pumping is 200 gal. per minute.

From Table 16, the head loss due to friction in the discharge pipe is $5.52 \times 2.3 \times 481 \div 100 = 61$.

From Table 16, the head loss due to friction in the suction pipe is $1.35 \times 2.3 \times 24 \div 100 = 0.75$ ft.

From Table 17, the head loss due to bends on the suction line is $3 \times 0.172 \times 2.3 = 1.19$ ft.

From Table 17, the head loss due to bends on the discharge line is $3 \times 0.512 \times 2.3 = 3.53$ ft.

From Table 21, the head loss in the 3-in. gate valve is 0.20 ft.

From Table 23, the velocity in the suction pipe is 5 ft. per second, and in the discharge pipe it is 8.7 ft. per second, giving velocity heads of 0.39 and 1.17 ft., respectively.

The total lift is therefore $61.0 + 0.75 + 1.19 + 3.53 + 0.20 + 0.39 + 1.17 + 170 = 238.23$ ft.

The height to which water can be lifted by suction is limited by atmospheric pressure and the temperature (vapor tension) of the water. It can be expressed as follows:

$$L = A - T - F.$$

TABLE 16.—LOSS OF PRESSURE IN CLEAN IRON PIPE
(Pounds per square inch per 100 feet of pipe)[1]

Flow in gallons per minute	Diameter of pipe in inches									Flow in gallons per minute	Diameter of pipe in inches			
	½	¾	1	1¼	1½	2	2½	3	4		6	8	10	12
5	15.4	3.8	0.80	0.25	0.12	0.035	0.026	....	....	100	0.043	0.013	0.005	0.002
10	52.6	13.0	3.16	1.00	0.47	0.12	0.05	....	....	150	0.10	0.026	0.010	0.004
15	117.0	28.8	7.00	2.18	1.00	0.25	0.11	0.01	....	200	0.18	0.044	0.016	0.007
20	....	50.4	12.3	3.75	1.66	0.42	0.19	0.06	....	250	0.29	0.066	0.023	0.010
25	....	77.5	19.2	5.61	2.60	0.65	0.29	0.10	....	300	0.40	0.092	0.032	0.014
30	....	110	27.5	7.70	3.75	0.91	0.40	0.13	....	350	0.50	0.12	0.043	0.018
35	....	....	37.8	11.0	5.14	1.26	0.53	0.18	....	400	0.65	0.16	0.055	0.023
40	....	....	48.0	14.2	6.52	1.60	0.68	0.23	0.07	450	0.81	0.20	0.069	0.029
45	....	....	61.5	18.1	8.26	2.02	0.85	0.29	0.09	500	1.00	0.24	0.084	0.035
50	....	....	75.0	22.0	10.0	2.44	1.03	0.35	0.10	600	1.43	0.35	0.12	0.049
55	....	....	92.5	26.7	12	2.97	1.23	0.43	....	700	1.91	0.47	0.16	0.066
60	....	....	110	31.3	14	3.50	1.48	0.50	....	800	2.51	0.61	0.21	0.085
70	....	....	....	42.3	20	4.80	1.91	0.68	0.19	900	3.17	0.77	0.26	0.11
80	....	....	....	55.0	25.0	6.30	2.30	0.88	....	1,000	3.90	0.94	0.32	0.13
90	....	....	....	69.4	31.5	7.85	2.81	1.06	....	1,200	5.60	1.35	0.45	0.19
100	....	....	....	85.0	39.0	9.46	3.70	1.31	0.38	1,400	7.60	1.83	0.61	0.25
120	....	....	....	....	....	15.6	5.20	2.15	0.55	1,600	9.90	2.38	0.79	0.32
150	....	....	....	....	....	23.4	8.09	3.35	0.79	1,800	12.5	3.00	1.00	0.41
175	....	....	....	....	....	....	10.2	4.21	1.04	2,000	15.4	3.69	1.23	0.50
200	....	....	....	....	....	....	13.4	5.52	1.35	2,500	....	5.75	1.90	0.77
250	....	....	....	....	....	....	....	8.51	2.08	3,000	....	....	2.73	1.10
300	....	....	....	....	....	....	....	18.70	2.90	3,500	....	....	....	1.50
350	....	....	....	....	....	....	....	....	3.65	4,000	....	....	....	1.70
400	....	....	....	....	....	....	....	....	4.75	4,500	....	....	....	2.09
450	....	....	....	....	....	....	....	....	6.00	5,000	....	....	....	2.53
500	....	....	....	....	....	....	....	....	7.39					

[1] These figures are only approximate, as much depends on the character of the inside surface of the pipe. These figures are for smooth pipe. For rough pipe add 15 per cent, and for very rough pipe add 30 per cent.

TABLE 17.—LOSS OF PRESSURE IN 90-DEG. ELBOWS
(Pounds per square inch)[1]
(See also Tables 18, 19 and 20)

Flow, g.p.m.	Diameter of pipe, inches										Flow, g.p.m.	Diameter pipe, inches		
	½	¾	1	1¼	1½	2	2½	3	4	6		8	10	12
5	0.40	0.080	0.025	0.013	.....	0.002	.....	.....	.....	.....	100	0.003		
10	1.60	0.318	0.100	0.041	0.020	0.006	0.003	.....	.....	.....	125	0.004	0.002	
15	3.60	0.715	0.225	0.092	0.045	0.014	0.005	.....	.....	.....	150	0.006	0.003	
20	6.40	1.27	0.400	0.164	0.079	0.025	0.010	0.005	.....	.....	175	0.009	0.004	
25	10.0	1.99	0.625	0.256	0.124	0.039	0.016	0.008	.....	.....	200	0.011	0.005	
30	.....	2.86	0.900	0.369	0.178	0.056	0.023	0.011	.....	.....	250	0.017	0.007	
35	.....	3.90	1.23	0.502	0.243	0.077	0.031	0.015	.....	.....	300	0.025	0.010	
40	.....	5.09	1.60	0.656	0.317	0.100	0.041	0.020	0.007	.....	350	0.034	0.014	
45	.....	6.45	2.03	0.830	0.402	0.127	0.052	0.026	0.009	.....	400	0.044	0.018	
50	.....	7.95	2.50	1.25	0.495	0.156	0.064	0.032	0.010	.....	450	0.057	0.023	
60	.....	.....	3.60	1.48	0.714	0.225	0.092	0.044	0.015	0.003	500	0.068	0.028	0.017
70	.....	.....	4.90	2.01	0.971	0.306	0.125	0.060	0.021	0.004	750	0.156	0.063	0.031
80	.....	.....	6.40	2.62	1.27	0.400	0.164	0.080	0.027	0.005	1,000	0.272	0.112	0.062
90	.....	.....	8.10	3.32	1.60	0.506	0.207	0.104	0.035	0.007	1,250	0.435	0.175	0.008
100	.....	.....	10.0	4.10	1.98	0.625	0.255	0.128	0.043	0.008	1,500	0.624	0.252	0.128
125	.....	.....	.....	6.42	3.10	0.976	0.400	0.200	0.067	0.013	2,000	1.08	0.446	0.207
150	.....	.....	.....	9.22	4.45	1.41	0.575	0.286	0.096	0.019	2,500	1.63	0.693	0.331
175	.....	.....	.....	.....	6.08	1.92	0.782	0.390	0.132	0.026	3,000	.....	0.995	0.476
200	.....	.....	.....	.....	7.93	2.50	1.02	0.512	0.172	0.032	3,500	.....	1.35	0.650
250	.....	.....	.....	.....	.....	3.86	1.60	0.800	0.268	0.055	4,000	.....	.....	0.849
300	.....	.....	.....	.....	.....	5.63	2.30	1.14	0.384	0.076	4,200	.....	.....	0.968
350	.....	.....	.....	.....	.....	.....	4.09	1.58	0.530	0.103	4,500	.....	.....	1.07
400	.....	.....	.....	.....	.....	10.0	5.12	2.05	0.688	0.128	5,000	.....	.....	1.33
450	.....	.....	.....	.....	.....	.....	6.20	2.58	0.870	0.170				
500	.....	.....	.....	.....	.....	.....	7.64	3.20	1.11	0.280				
750	.....	.....	.....	.....	.....	.....	.....	.....	2.42	0.470				
1,000	.....	.....	.....	.....	.....	.....	.....	.....	4.28	0.832				
1 250	.....	.....	.....	.....	.....	.....	.....	.....	6.70	1.31				
1,500	.....	.....	.....	.....	.....	.....	.....	.....	9.68	1.88				

[1] Computed from Weisbach formula $H_e = (0.131 + 1.847 \left(\frac{r}{R}\right)^{3.5} \times \frac{V^2}{2g} \times \frac{a}{180}$.

H_e = head loss in pounds per square inch
r = internal radius.
R = radius of axis of pipe.
V = velocity feet per second.
a = central angle or angle subtended by the bend, in degree
These figures are approximations of the actual quantities.

in which L = the limiting suction lift.
A = the atmospheric pressure.
T = the vapor tension.
F = all friction losses plus the velocity head.

The normal atmospheric pressure at different elevations above sea level are shown in Table 24 and vapor tensions at various temperatures are shown in Table 25.

TABLE 18.—LOSSES OF PRESSURE IN FITTINGS AND VALVES
(*John R. Freeman*)

Description	Equivalent length of straight pipe of same diameter, feet
6-in. swing-check valve	50
6-in. lift-check valve	200
4-in. swing-check valve	25
4-in. lift-check valve	130
2½- to 8-in. long-turn ells	4
2½- to 8-in. short-turn ells	9
3- to 8-in. long-turn tees	9
3- to 8-in. short-turn tees	17
⅛ bend (45 deg.)	5
6-in. Grinnel dry pipe valve	80
4-in. Grinnel dry pipe valve	47
6-in. Grinnel alarm check valve	100
4-in. Grinnel alarm check valve	47

Example.—Compute the maximum suction lift under the conditions shown in Fig. 25 assuming that the temperature of the water is 60° F. and that the pump is 5,000 ft. above sea level

From Table 24, A = 28.4 ft.

From Table 25, T = 0.26 ft.

From the previous example F = 0.39 (entrance head) + 0.75 (friction loss in suction pipe) + 1.08 (friction loss in bends in the suction pipe) + 0.39 (one velocity head) = 2.61 ft.

Therefore L = 28.4 − 0.26 − 2.61 = 25.5 ft.

The theoretical amount which water can be lifted by suction at various altitudes and temperatures is shown in Table 26. It is computed on the basis that 1 cu. ft. of water weighs 62.5 lb.

TABLE 19.—LOSSES OF PRESSURE IN PIPES AND FITTINGS
(Computed from data by F. E. Giesecke in University of Texas *Bulletin* of Oct. 20, 1917)

Description of pip or fitting, inches	Head lost per foot or per fitting in feet of water in terms of velocity of flow expressed as $H = KV^n$		Loss of head in feet of water per foot or per fitting for flow, in gallons per minute, of									
	K	n	2.5	5	10	15	20	25	35	50	75	100
½ black pipe	0.014335	1.7776	0.085	0.29	0.95	1.89	3.2	4.74	8.6			
¾ black pipe	0.00855	1.812	0.018	0.063	0.22	0.45	0.776	1.13	2.1	4.02	8.2	
1 black pipe	0.006371	1.7767	....	0.019	0.065	0.13	0.22	0.33	0.60	1.12	2.23	3.8
1¼ black pipe	0.004675	1.756	....	....	0.018	0.047	0.061	0.09	0.16	0.30	0.61	1.011
1½ black pipe	0.003228	1.7998	....	0.0021	0.00074	0.015	0.025	0.038	0.069	0.13	0.27	0.46
2 black pipe	0.00253	1.6787	....	....	0.00085	0.002	0.0036	0.0059	0.019	0.025	0.061	0.11
2½ black pipe	0.00253	1.735	....	....	0.00016	0.00030	0.00047	0.00067	0.0011	0.0020	0.0037	0.0068
3 black pipe	0.00166	1.679	....	....	....	....	0.00013	0.00019	0.00034	0.00060	0.0012	0.0019
1¼ galvanized pipe	0.005139	1.789	....	....	0.020	0.041	0.070	0.10	0.19	0.36	0.74	1.23
1½ galvanized pipe, new	0.003373	1.8115	....	....	0.010	0.020	0.032	0.047	0.083	0.15	0.30	0.50
1½ galvanized pipe, old	0.003935	1.927	....	....	0.0084	0.015	0.036	0.055	0.105	0.21	0.46	0.80
¾ unreamed ends	0.01024	1.375	0.019	0.048	0.12	0.21	0.32	0.43	0.68	1.08		
1 inreamed ends	0.004575	2.128	0.0037	0.016	0.068	0.16	0.283	0.46	0.93	1.95	4.6	8.50
¾ coupling	0.001465	1.139	0.0021	0.0047	0.0105	0.017	0.024	0.031	0.046	0.070		
1 coupling	0.000625	1.1213	....	....	0.0022	0.0039	0.0059	0.0083	0.0135	0.016	0.041	0.063
½ elbow	0.0180	1.945	0.15	0.51	1.73	3.52	5.80	8.60	15.5	29.0		
¾ elbow	0.01344	1.856	0.030	0.016	0.38	0.80	1.35	2.05	3.80	7.35	15.4	26.2
1 elbow	0.01358	1.896	0.012	0.045	0.166	0.36	0.611	0.94	1.76	3.45	7.50	
1½ elbow	0.01405	2.0076	0.00228	0.0090	0.036	0.081	0.144	0.224	0.43	0.89	2.00	3.57
2 elbow	0.010574	1.963	....	....	0.0098	0.0215	0.0378	0.0585	0.113	0.223	0.50	0.83
2½ elbow	0.01212	1.979	0.00037	0.00142	0.0056	0.0125	0.0200	0.0340	0.0652	0.132	0.33	0.52
1¼ elbow, short radius	0.0111	2.0819	0.0307	0.0127	0.055	0.127	0.231	0.370	0.733	1.53	3.54	6.51
1½ elbow, long radius	0.003322	2.784	....	0.043	0.029	0.088	0.182	0.353	0.894	2.32	7.15	16.65
1¼ drainage elbow, short radius	0.02009	1.9522	....	....	0.086	0.189	0.331	0.510	0.975	1.98	4.41	7.85
1¼ drainage elbow, long radius	0.008981	2.0745	0.0025	0.0105	0.044	0.102	0.185	0.291	0.584	1.21	2.80	5.11
	0.008649	1.869	0.0027	0.0098	0.036	0.076	0.131	0.200	0.372	0.722	1.54	2.64

TABLE 20.—FRICTION IN PIPE FITTINGS

(Expressed as number of feet of straight pipe which will give same pressure loss for same rate of flow. These figures are only approximate and may vary 200 to 300 per cent)

Size of fitting, inches	¾	1	1¼	1½	2	2½	3	4	5	6
Elbows[1]	5	5	6	7	7	10	12	18	25	30
Elbows[2]	2.5	3.3	4.1	5	5	8.3	10	18.3		
Elbows[3]	2.6	3.4	4.1	4.8	6.3	7.8	9.2	12.1	15	18
Return bends[1]	10	10	12	14	15	20	24	36	50	60
Globe valves[1]	6	6	7	8	8	12	24	30	40	50

[1] HARDING and WILLARD, "Mechanical Equipment of Buildings," Vol. II, p. 346.

[2] TIMMIS, W. S., Journal American Society Heating and Ventilating Engrs., Vol. 28, p. 397, 1922.

[3] Computed from Tables 16 and 17.

TABLE 21.—LOSS OF HEAD IN GATE VALVES

(University of Wisconsin tests by Chas. I. Corp)

(Losses expressed in feet)

Discharge, g.p.m.	Diameter of valve, inches												Discharge, g.p.m.
	½	¾	1	1½	2	3	4	5	6	8	10	12	
5	0.4	0.04											
10	1.5	0.17	0.05										
15	3.3	0.4	0.12	0.017									
20	5.7	0.7	0.20	0.03	0.010								
30	12	1.5	0.45	0.07	0.023								
40	21	2.7	0.80	0.13	0.040								
50	....	4.3	1.2	0.19	0.062	0.013							
75	....	....	2.7	0.44	0.14	0.028							
100	....	....	....	0.76	0.25	0.05	0.016						
150	....	....	....	1.7	0.55	0.12	0.037	0.014					
200	....	....	....	3.1	0.97	0.20	0.065	0.025	0.010	....	....	....	200
250	....	....	....	9.8	1.5	0.31	0.10	0.039	0.015	....	....	....	250
300	....	....	....	....	2.2	0.45	0.14	0.055	0.021	....	....	....	300
400	....	....	....	....	3.9	0.8	0.25	0.11	0.039	0.010	....	....	400
500	....	....	....	....	....	1.2	0.40	0.15	0.060	0.015	....	....	500
750	....	....	....	....	....	2.7	0.90	0.34	0.13	0.035	0.012	....	750
	....	....	....	....	....	5.0	1.6	0.61	0.24	0.062	0.020	....	1,000
	....	....	....	....	....	....	3.6	1.4	0.55	0.14	0.046	0.013	1,500
	....	....	....	....	....	....	....	2.4	0.96	0.25	0.083	0.024	2,000
	....	....	....	....	....	....	....	....	2.2	0.55	0.18	0.054	3,000
	....	....	....	....	....	....	....	....	3.9	0.98	0.33	0.097	4,000
	....	....	....	....	....	....	....	....	....	1.5	0.63	0.15	5,000
	....	....	....	....	....	....	....	....	....	2.2	0.74	0.22	6,000
	....	....	....	....	....	....	....	....	....	3.5	1.2	0.35	7,500
	....	....	....	....	....	....	....	....	....	....	2.0	0.61	10,000

TABLE 22.—LOSS OF HEAD IN VALVES: GATE, GLOBE, ANGLE, CHECK AND GROUND-KEY
(Losses in feet)

Discharge, g.p.m.	1 in. gate, University of Illinois[1]	1-in. globe, University of Illinois[1]	1-in. angle, University of Illinois[1]	1-in. ground key, University of Illinois	1½-in. gate, Purdue[2]	1½-in. globe Purdue[2]	1½-in. check, Purdue[2]	1¼-in. ground key, University of Illinois	Discharge, g.p.m.	2-in. gate, University of Illinois[1]	2-in. globe, University of Illinois[1]	2-in. angle, University of Illinois[1]	2-in. ground key, University of Illinois
5	.....	.....	.....	.....	.....	0.2	0.5	.....	30	.....	0.7	0.3	
10	0.2	1.5	0.6	.....	.....	0.7	0.9	.....	40	.....	1.2	0.5	
15	0.3	3.2	1.6	.....	0.8	1.4	1.7	.....	50	.....	1.8	0.8	
20	0.6	6.1	2.9	.....	1.2	2.5	3.0	.....	75	0.1	4.0	1.2	
30	1.4	13.9	6.1	.....	2.5	4.3	6.7	.....	100	0.4	6.6	2.0	
40	2.6	25	11.8	.....	4.1	10.8	13	.....	150	0.9	16	4.8	
50	4.0	38	17.5	.....	6.5	13	19	.....	200	1.8	28	8.6	
75	8.7	.....	36	.....	12.6	32	39	.....	250	2.6	.....	12.7	
100	.....	.....	.....	.....	.....	.....	.....	.....	300	3.6	.....	17	

[1] *Bull.* 105, Eng. Expt. Station, 1918.
[2] *Bull.* 1, Eng. Expt. Station, 1918.

39. Power Required to Drive a Pump.—The horsepower of the motor required to drive a pump can be computed from the following expression:

$$P = \frac{L \times Q \times 8.3}{33{,}000 \times E},$$

in which

P = the horsepower to be delivered by the motor to the pump.
L = the total lift for the pump, expressed in feet. The lift is to be computed as explained in Sec. 38.
Q = the rate of discharge from the pump in gallons per minute.
E = the sum of the mechanical efficiency of the pump and the belt, gearing, or shafting by which the power of the motor is transmitted to the pump.

The efficiencies of various forms of power transmission are stated in Sec. 32.

40. Storage Tanks.—When the pressure in a water supply is irregular, uncertain, or intermittent, some method is necessary to obtain water in the plumbing system when the pressure in the water supply is low. Two principal methods are used: (1) a gravity storage tank, and (2) a pneumatic storage tank.

TABLE 23.—VELOCITY OF FLOW IN PIPE
(Feet per second)

G.p.m.	Standard wrought pipe													Cast-iron soil and water pipe		Vitrified-clay pipe			
	½	¾	1	1¼	1½	2	2½	3	3½	4	5	6	8	2	3	4	5	6	8
5	5.25	3.0	1.85	1.07	0.79	0.48	0.33	0.22	0.16	0.13	0.08	0.055	0.03	0.51	0.23	0.13	0.08	0.06	0.03
10	10.5	6.0	3.71	2.14	1.58	0.96	0.67	0.43	0.32	0.25	0.16	0.11	0.06	1.02	0.45	0.26	0.16	0.11	0.06
15	15.7	9.0	5.56	3.21	2.36	1.43	1.00	0.65	0.49	0.38	0.24	0.17	0.09	1.53	0.68	0.38	0.24	0.17	0.10
20	21.0	12.0	7.42	4.28	3.15	1.91	1.34	0.87	0.65	0.50	0.32	0.22	0.13	2.04	0.91	0.51	0.33	0.23	0.13
25	26.3	15.0	9.28	5.33	3.95	2.39	1.67	1.06	0.81	0.63	0.40	0.28	0.15	2.55	1.13	0.64	0.41	0.28	0.16
30	31.5	18.0	11.13	6.42	4.73	2.87	2.01	1.30	0.97	0.75	0.48	0.33	0.19	3.05	1.36	0.77	0.49	0.34	0.19
35	....	21.0	13.0	7.49	5.50	3.34	2.34	1.52	1.13	0.88	0.56	0.39	0.22	3.56	1.58	0.89	0.57	0.40	0.22
40	....	24.0	14.8	8.56	6.30	3.82	2.68	1.74	1.30	1.00	0.64	0.44	0.25	4.07	1.81	1.02	0.65	0.45	0.26
45	....	27.0	16.8	9.64	7.10	4.29	3.01	1.97	1.46	1.13	0.72	0.50	0.28	4.57	2.04	1.14	0.73	0.51	0.29
50	....	30.0	18.5	10.7	7.88	4.78	3.35	2.17	1.62	1.27	0.80	0.55	0.31	5.09	2.26	1.28	0.82	0.57	0.32
60	....	....	22.2	12.8	9.46	5.74	4.02	2.60	1.94	1.50	0.96	0.66	0.38	6.10	2.72	1.54	0.98	0.68	0.38
70	....	....	26.0	15.0	11.0	6.68	4.68	3.04	2.26	1.76	1.12	0.78	0.44	7.12	3.16	1.78	1.14	0.80	0.44
80	....	....	30.0	17.1	12.6	7.64	5.36	3.48	2.60	2.00	1.28	0.88	0.50	8.14	3.62	2.04	1.30	0.90	0.52
90	....	....	....	19.3	14.2	8.58	6.02	3.94	2.92	2.26	1.44	1.00	0.56	9.14	4.08	2.28	1.46	1.02	0.58
100	....	....	....	21.4	15.8	9.55	6.69	4.34	3.24	2.51	1.60	1.11	0.63	10.2	4.53	2.55	1.63	1.13	0.64
150	....	....	....	32.1	23.6	14.3	10.0	6.50	4.86	3.77	2.40	1.66	0.94	15.3	6.79	3.82	2.44	1.69	0.95
200	....	....	....	....	31.5	19.1	13.4	8.68	6.48	5.02	3.20	2.22	1.26	20.4	9.06	5.10	3.26	2.26	1.28
300	....	....	....	....	....	28.7	20.1	13.0	9.72	7.53	4.80	3.33	1.89	30.5	13.6	7.65	4.89	3.39	1.92
500	....	....	....	....	....	....	33.5	21.7	16.2	12.7	8.00	5.55	3.15	....	22.6	12.8	8.15	5.65	3.20
750	....	....	....	....	....	....	....	32.5	24.3	18.8	12.0	8.31	4.68	....	34.0	19.2	12.2	8.36	4.79
1,000	....	....	....	....	....	....	....	....	32.4	25.1	16.0	11.1	6.25	....	....	25.5	16.3	11.3	6.37

TABLE 24.—ATMOSPHERIC PRESSURE IN FEET OF WATER AT VARIOUS ALTITUDES ABOVE SEA LEVEL
(Temperature 50° F.)

Elevation above sea level, feet	Atmospheric pressure feet of water	Elevation above sea level, feet	Atmospheric pressure, feet of water	Elevation above sea level, feet	Atmospheric pressure, feet of water	Elevation above sea level, feet	Atmospheric pressure, feet of water
0	34.0	2,000	31.5	4,000	29.4	6,000	27.4
500	33.3	2,500	31.0	4,500	28.9	7,000	26.4
1,000	32.7	3,000	30.4	5,000	28.4	8,000	25.5
1,500	32.1	3,500	29.9	5,500	27.9	10,000	23.7

TABLE 25.—VAPOR TENSION IN FEET OF WATER

Temperature, degrees Fahrenheit	Pressure, pounds per square inch	Pressure, feet of water	Temperature, degrees Fahrenheit	Pressure, pounds per square inch	Pressure, feet of water	Temperature, degrees Fahrenheit	Pressure, pounds per square inch	Pressure, feet of water
32	0.09	0.21	100	0.95	2.19	180	7.53	17.4
40	0.12	0.28	120	1.69	3.91	200	11.56	26.7
60	0.26	0.60	140	2.89	6.68	212	14.70	34.0
80	0.50	1.15	160	4.74	11.0			

TABLE 26.—MAXIMUM THEORETICAL SUCTION LIFT OF PUMPS, IN FEET

Temperature, degrees Fahrenheit	Elevation above sea level, feet										
	0	500	1,000	1,500	2,000	2,500	3,000	4,000	5,000	7,000	10,000
40	33.7	33.0	32.4	31.8	31.2	30.7	30.1	29.1	28.1	26.1	23.4
60	33.4	32.7	32.1	31.5	30.9	30.4	29.8	28.8	27.8	25.8	23.1
80	32.8	32.1	31.5	30.9	30.3	29.8	29.2	28.2	27.2	25.2	22.5
100	31.8	31.1	30.5	29.9	29.3	28.8	28.2	27.2	26.2	24.2	21.5
120	25.0	24.3	23.7	23.1	22.5	22.0	21.4	20.4	19.4	17.4	14.7
160	23.0	22.3	21.7	21.1	20.5	20.0	19.4	18.4	17.4	15.4	12.7
180	16.6	15.9	15.3	14.7	14.1	13.6	13.0	12.0	11.0	9.0	6.3

41. Gravity Storage Tanks.—The gravity storage tank is placed at an elevation above all points where water is needed; it may be on the roof, in the attic, on a tower, or on a hill. In very tall buildings gravity storage tanks are placed on intermediate floors to minimize the pressures on the lower floors. During periods of high pressure in the water-supply system, such as might occur when the pumps are running, or the windmill is operating, or the pressure is increased in the public supply, water is delivered into the storage tank. When the pressure in the water supply is reduced water will flow from the storage tank into the pipes of the plumbing system. A water-supply system dependent on a gravity tank is shown in Fig. 28A. The tank must be equipped with an automatic valve, usually controlled by a float, to shut off the supply when the tank is full, and with an overflow of sufficient capacity to carry off water faster than it can be supplied to the tank. The top of the overflow pipe should be at least 3 in. below the top of the tank and no air vent should be inserted in the overflow pipe. If the tank is placed above a building, provision must be made to conduct away leakage or, in case of the failure of the tank, to conduct the water away quickly without damage to the building. The tank should be provided, also, with a telltale to indicate when the tank is full, a distributing pipe to furnish water from the tank to the pipes in the building, and a drain pipe through which the tank can be emptied.

Outside storage tanks, whether of wood or of metal, should have a weathertight and fireproof roof so arranged as to exclude birds. The purpose of the roof is to protect the water from inevitable pollution by birds, dust, and dirt in the air and to aid in preventing the formation of ice. The roof must not be airtight. It must be vented so as to permit the rapid filling or emptying of the tank without the creation of a pressure or a vacuum under the roof. In any outside tank an expansion joint as shown in Fig. 35 should be used on any pipe passing through the tank.

The water supply to a storage tank may come through the same or a different pipe than the pipe used to deliver water from the tank. If separate pipes are used the incoming water pipe may rise outside or inside of the tank. An outside location makes repairs easy but exposes more of the pipe to freezing temperatures.

TABLE 27.—CAPACITIES PER FOOT HEIGHT OF VERTICAL CYLINDRICAL TANKS IN GALLONS

Diameter, feet....	2	2½	3	3½	4	4½	5	6	7	8	9	10	12
Capacity.........	23.5	36.8	52.8	72.1	94.0	119	147	211.5	288.1	376.3	477.3	589.0	850

TABLE 28.—SPACING OF HOOPS ON CYLINDRICAL WOODEN TANKS. DISTANCE FROM TOP OF TANK TO HOOP, FEET[1]
(All hoops ¾-inch diameter)

Hoop number below top of tank	Diameter of tank in feet							
	4	5	6	7	8	9	10	12
1	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
2	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
3	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
5	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2
6	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9
7	10.7	10.7	10.7	10.7	10.7	10.7	10.3	10.3
8	12.4	12.4	12.4	12.4	12.2	12.2	11.7	11.5
9	14.2	14.2	14.2	13.1	13.7	13.6	13.0	12.6
10	15.9	15.9	15.9	15.5	15.0	14.9	14.1	13.6
11	17.7	17.7	17.5	16.8	16.2	16.0	15.2	14.5
12	19.4	19.3	19.0	18.1	17.3	17.0	16.2	15.5
13	21.2	20.8	20.3	19.3	18.2	18.0	17.2	16.4
14	......	......	......	20.4	19.2	19.0	18.0	17.1
15	......	......	......	......	20.2	19.8	18.8	17.8
16	......	......	......	......	......	20.5	19.6	18.5
17	......	......	......	......	......	......	20.4	19.2
18	......	......	......	......	......	......	......	19.9
19	......	......	......	......	......	......	......	20.6

[1] Computed on basis that working stress on net area of metal under threads (no upset bars allowed) is 16,000 lb. per square inch and otherwise in accordance with specifications of Associated Factory Mutual Fire Insurance Companies.

[2] An extra hoop must be placed around the bottom of the tank, as a factor of safety.

Example: a. In a 12-ft. diameter tank, 20 ft. deep, how far is it from the top down to the tenth hoop? 13.6 ft. *Ans.*

b. In a 10-ft. diameter tank, 15 ft. deep, how many hoops are there, including the extra one at the bottom? 11. *Ans.*

c. What is the deepest tank 7 ft. in diameter which can be built, using 10 hoops? 13.1 ft. *Ans.*

The size of a gravity storage tank is dependent on the demand for water between periods of high pressure in the water supply. It can be determined only by local conditions and generalizations can be only suggestive. In such extreme situations where pressure is available during the night only and the entire day's supply must be stored in the tank, there should not be less than 80 gal. for each person depending on the tank for supply. Too large a tank, however, may result in complaints of the quality of the water due to the generation of odors, too high a temperature, or other difficulties arising from too long a period of storage. The capacities of vertical cylindrical tanks are given in Table 27.

Gravity storage tanks are made of wood, metal, and in some cases of concrete. The woods commonly used are cypress, red cedar, white pine or Oregon pine (Douglas fir), and red pine (redwood). The tank is made up of wood staves which are held together by round iron hoops, the spacings and sizes of which are shown in Table 28. Round hoops are better than flat hoops as they can be easily examined when in place and can be more easily protected by paint and there is less surface exposed to the atmosphere than for any other shape containing the same quantity of metal. Welded or upset hoops should not be used because of danger from weakness in the weld. The hoop ends are joined by means of a lug, shown in Fig. 27. In placing the hoops on a tank the lugs should not be placed in the same vertical line. Wooden tanks are less expensive than metal tanks in first cost; they will last, with care, for 12 to 30 years; they furnish better protection against freezing; they require less skill in erection; and they do not sweat. Metal tanks will usually outlast wooden tanks and there is less likelihood of leakage from them.

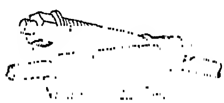


FIG. 27.—Lugs for hoops for wooden tanks.

Possible objections to the use of gravity tanks in a building include the extra weight to be supported by the frame of the building, the cost of the tower if placed elsewhere than on a building or a hill, possible contamination of the water or change in its quality, the possible freezing of the water, and other difficulties. These can all be overcome, but at somewhat increased expense, by the use of a pneumatic storage tank.

42. Pneumatic Storage Tanks.—A pneumatic storage tank is a closed airtight tank filled partly with water and partly with

air. The inlet and outlet pipes for the water enter through the bottom of the tank. Compressed air is pumped into the tank through an air pipe at the top. In the operation of the tank water is pumped into it thus compressing the air entrained until the tank is about two-thirds full of water. Additional compressed air is then forced in over the top of the water. A check valve in the inlet pipe prevents the backflow of water into the pipes supplying water to the tank. When the pressure in the water supply lines becomes low the pressure due to the compressed air in the tank furnishes the necessary force to move water to the points desired in the plumbing system. An air compressor is necessary to supply the initial air pressure and to make up for the loss of air from the tank. This loss may be appreciable because the pressure on the water entering the tank is increased thus rendering air more soluble in it. The solubility of gases in water increases with the pressure.

TABLE 29.—AIR AND WATER PRESSURES IN PNEUMATIC STORAGE TANKS

Minimum discharge pressure, pounds per square inch[1]	0	10	20	30	40	50	60	70	80	90	100
Maximum discharge pressure, pounds per square inch[2]	30	60	90	120	150	180	210	240	270	300	330
Ratio maximum to minimum pressure	∞	6	4.5	4	3.75	3.6	3.5	3.4	3.3	3.3	3.3

[1] Tank full of air.
[2] Tank two-thirds full of water and one-third full of air.

The minimum pressure when there is no water in the tank and the maximum pressure when the tank is two-thirds full of water are shown in Table 29. Wide variations in pressure are undesirable and uneconomical but are unavoidable with this type of storage. The same principles with regard to the capacity hold for pneumatic tanks as for gravity storage tanks. The effective capacity of water storage is taken as two-thirds of the full capacity of the tank. The liquid contents of circular tanks in a horizontal position at various depths are shown in Table 30 and the capacities per foot height of vertical cylindrical tanks are shown in Table 27. Manufacturer's standards for pneumatic storage tanks are given in Table 31.[5]

TABLE 30.—VOLUME IN GALLONS PER FOOT LENGTH OF HORIZONTAL CIRCULAR TANKS AT VARIOUS DEPTHS IN THE TANK

Depth in tank, inches	Diameter of tank, inches								
	16	20	24	30	36	42	48	60	72
2	0.75	0.84	0.94	1.04	1.14	1.24	1.34	1.49	1.65
4	2.04	2.32	2.61	2.94	3.20	3.5	3.8	4.2	4.6
6	3.68	4.11	4.6	5.2	5.8	6.3	6.8	7.5	8.4
8	5.22	6.1	6.9	7.9	8.7	9.5	10.4	11.6	12.8
10	6.8	8.2	8.8	10.7	11.9	13.1	14.1	16.3	17.8
12	8.4	10.2	11.8	13.7	15.8	17.0	18.3	20.5	23.3
14	9.6	12.2	14.7	16.8	18.8	21.1	23.2	26.0	28.8
16	10.4	14.0	16.6	20.0	22.6	24.9	27.4	31.0	34.9
18	......	15.5	18.9	23.1	26.4	29.2	32.8	36.9	41.3
20	......	16.3	20.9	26.1	30.2	33.9	37.9	42.4	48.1
22	......	......	22.6	28.9	34.0	38.2	42.0	48.0	54.6
24	......	......	23.5	31.6	37.0	42.9	47.0	54.0	61.8
26	......	......	......	33.9	40.9	47.2	52.0	61.0	69.0
28	......	......	......	35.8	44.1	51.0	56.1	67.1	76.2
30	......	......	......	36.8	47.0	55.1	61.2	73.5	83.6
32	......	......	......	......	49.6	59.0	66.6	79.9	91.2
34	......	......	......	......	51.7	62.6	70.8	86.0	96.5
36	......	......	......	......	52.8	65.8	75.7	93.0	105.7
38	......	......	......	......	......	68.6	79.9	99.0	115.0
40	......	......	......	......	......	70.9	83.6	104.6	120.3
42	......	......	......	......	......	72.1	87.2	110.1	127.9
44	......	......	......	......	......	......	90.2	116.0	135.3
46	......	......	......	......	......	......	92.7	121.0	142.5
48	......	......	......	......	......	......	94.0	126.5	149.7
50	......	......	......	......	......	......	......	130.7	156.9
52	......	......	......	......	......	......	......	135.4	163.4
54	......	......	......	......	......	......	......	139.5	170.2
56	......	......	......	......	......	......	......	142.8	176.6
58	......	......	......	......	......	......	......	145.5	182.7
60	......	......	......	......	......	......	......	147.0	188.2
62	......	......	......	......	......	......	......	......	193.7
64	......	......	......	......	......	......	......	......	198.7
66	......	......	......	......	......	......	......	......	203.1
68	......	......	......	......	......	......	......	......	206.9
70	......	......	......	......	......	......	......	......	209.8
72	......	......	......	......	......	......	......	......	211.5

TABLE 31.—MANUFACTURERS' STANDARD DIMENSIONS FOR PNEUMATIC TANKS IN INCHES

Vertical tanks

Size, inches	Capacity, gallons	Top to upper water-gage faucet	Top to center water-gage faucet	Bottom of tank to inlet	Opposite side to drain	Diameter of drain	Bottom to discharge	Diameter of outlet	Diameter of inlet
16 by 36	32	8½	13½	6	3	1	9	1	1
16 by 48	42	17	13½	6	3	1	9	1	1
20 by 60	82	23	13½	6	3	1	9	1	1
24 by 60	120	23	13½	6	6	1	9	1½	1½
30 by 72	220	29	13½	6	6	1	9	1½	1½
36 by 72	315	29	13½	6	6	1	9	2	2

Horizontal tanks

Size	Capacity, gallons	Water-gage opening	Center of water-gage opening	Inlet to outlet opening	Drain to inlet	Edge to drain	Diameter of drain opening	Diameter of outlet	Diameter of inlet
36 by 120	530	½	13½	8	8	8	1	2	2
42 by 120	720	½	21½	8	8	8	1	2	2
48 by 120	940	½	21½	10	8	8	1	2	2
48 by 288	2,260	½	21½	10	8	8	1	3	3
60 by 252	3,000	½	21½	10	8	8	1	3	3
72 by 288	5,000	½	21½	10	8	8	1	3	3

References

1. "Hydraulic-ram Installations," *Plumbers Trade Jour.*, Vol. 77, p. 1026, 1924.
2. Recommendations of the Hydraulic Society, 50 Church St., New York, 1922.
3. EVENS, E. M., "Pumping by Compressed Air," *Eng. and Contr.*, Mar. 17, 1915.
4. *Domestic Eng.*, p. 377, Dec., 2, 1922.
5. *Domestic Eng.*, p. 24, Mar. 22, 1924.

CHAPTER IV

WATER-SUPPLY AND DISTRIBUTING SYSTEMS

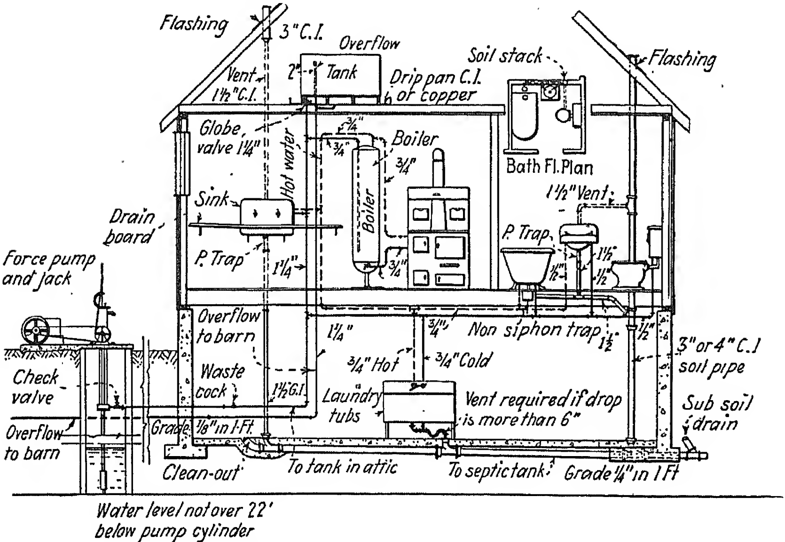
DESIGN, INSTALLATION, AND MAINTENANCE

43. Water-supply Systems.—The illustrations in Fig. 28 are taken from a bulletin on farm plumbing issued by the Agricultural Extension Department of the University of Illinois. These show the development of a water supply in a farm home from the simplest cistern and pitcher pump to a complete pressure system with both hot and cold water. In a building to which water is supplied from a street main, the main supply or service pipe to the building can be connected to the street main instead of to the pump shown in the figure.

Systems of supply pipes shown in Fig. 29 are suitable for use in taller buildings to avoid excessive pressures on the lower floors. This can be done by the installation of supply tanks on intermediate floors or by the use of pressure-regulating valves or by the use of separate supply systems.

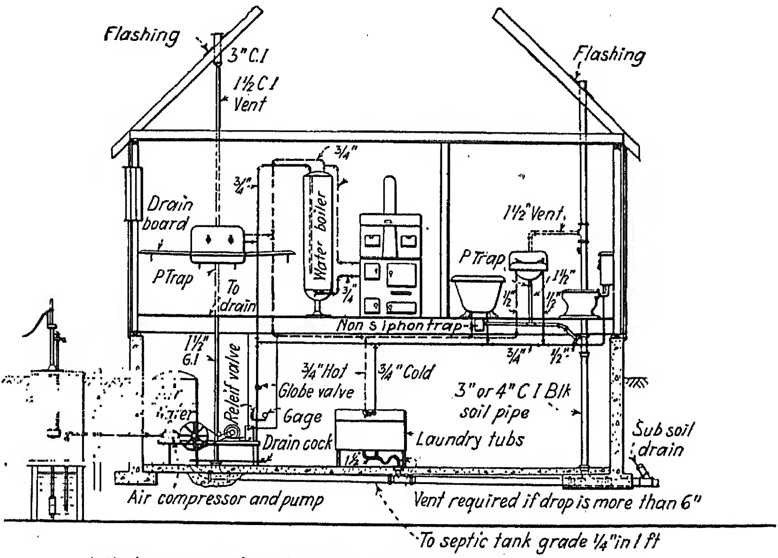
Dual, or double, water-supply systems are sometimes installed where one of the supplies is either impure, hard, or is otherwise unsatisfactory in quality. Where a supply is too polluted to be fit to drink, it should not be installed in such a situation that it can be used for drinking purposes. The faucets should be locked, or permanently and conspicuously labeled, or placed in inaccessible places. In general, the installation of any polluted water supply is not to be recommended. The principles involved in the installation of dual or multiple water supply systems are no different than for individual supplies. Cross-connections between good and bad water supplies should be avoided.

44. Water-supply Pipe Sizes.[1,2]—The rapidity with which water will be delivered to any plumbing fixture is dependent on the available pressure in the city main or from the private pump or storage tank, the number of obstructions in the supply pipe, and the size of the supply pipe. The size of the supply pipe, in turn, is dependent on:



A Gravity Water System & Complete Plumbing Equipment

(A)



A Hydropneumatic Water System & Complete Plumbing Equipment

(B)

FIG. 28.—Water-supply pipe arrangements for a residence. (*Circ.* 303, *Agr. College, Univ. of Ill.*)

In Fig. B the pump and well can be replaced by a service pipe to the public supply. Note the pressure-relief valve.

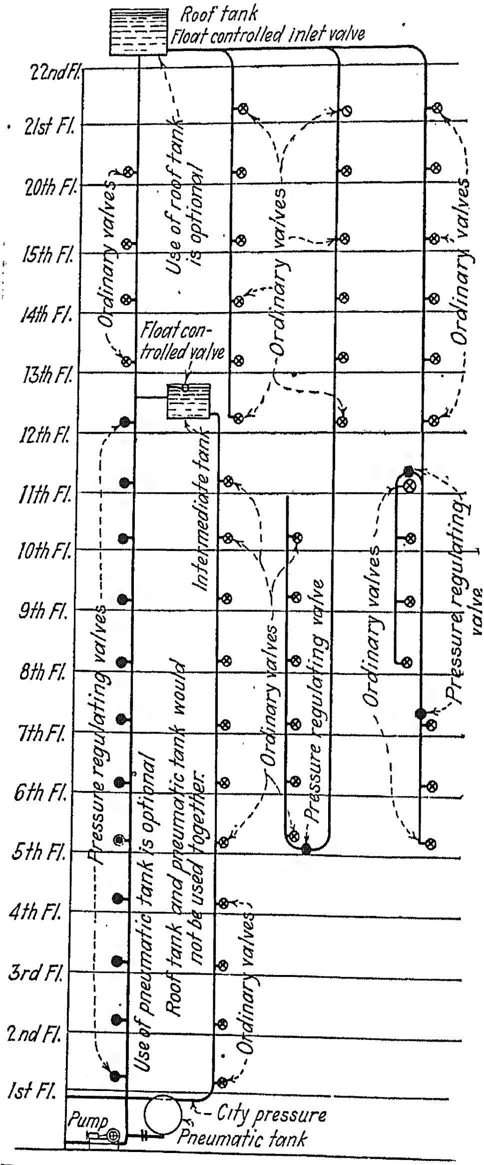


Fig. 29.—Systems of supply pipes for tall buildings

The available pressure.

The length of the pipe from the source to discharge.

The material of which the pipe is made.

The number of turns, reducers, valves, meters, and other obstructions on the line.

The rate at which water is to flow through the pipe. The losses of pressure (head) in a pipe due to various causes are shown in Tables 16 to 22, inclusive, and the velocity of flow in pipes is shown in Table 23.

The supply pressure in the street main or from the private pump should be between 30 and 70 lb. per square inch. Information concerning pressure in a public water supply is usually available from the waterworks department. The length of the service or supply pipe, the material of which it is made, the number of turns and fittings, etc. are read from the plans or are determined on the ground. The rate at which water is to be delivered by the pipe should be the sum of the rates of supply to each fixture, with proper allowance for the improbability of the simultaneous use of all of the fixtures, as discussed in Sec. 240. The average daily water consumption is not a factor in the determination of pipe sizes; the maximum rate of demand is the controlling factor. Since the prediction of the maximum rate of demand must be based, to a great extent, on judgment and experience, recommendations based on knowledge and experience will be helpful.

Tables 32, 33 and 34 are given to show recommended sizes of standard *wrought* pipe to be used under ordinary conditions. Table 32 shows the size of service pipe to use for a building, Table 33 shows the size or risers and main pipes within the building, and Table 34 shows the size of pipes to individual fixtures. Table 35 gives recommendations for the proper rates of flow to be provided for the fixtures and Table 36 gives the time required to fill a fixture. In some cases, because of its greater smoothness and workability, smaller-sized *brass* pipe is used with satisfaction. It is probable that the capacity of brass pipe is appreciably greater than that of standard wrought pipe. Little can be said, of a definite nature, with regard to the proper size of intermediate pipes between the service pipe and the branch pipe to the fixture except that the judgment of the designer must be exercised in this determination. His judgment must be based on the knowledge that no pipe should be smaller

TABLE 32.—RECOMMENDED SIZES OF SERVICE PIPES IN INCHES[1]
(Standard wrought pipe)

Class of building	Length of service pipe main to meter, feet			
	100	50	25	10
A.	1¼	1	1	¾
B.	1½	1¼	1¼	1
C.	2	1½	1½	1¼
D.	2	2	1½	1¼

[1] Computed on basis of 20 ft. loss of head from main to meter.

Notes: Class of building:

A. An ordinary single family dwelling,—two to two and a half stories, and not more than eight to ten rooms, containing one bathroom, a kitchen sink, laundry trays, and garden hose.

B. A two-family house or larger dwelling, up to about sixteen rooms, containing two bathrooms, two kitchen sinks, laundry trays, and one garden hose.

C. A four-apartment building of not more than six rooms each. Building contains four bathrooms, four kitchen sinks, four sets of laundry trays, and one garden hose.

D. A large apartment building containing not more than twenty-five apartments with a total of about one-hundred rooms; with full equipment of one bathroom and one kitchen, laundry trays for each apartment, and two hose connections for the building.

TABLE 33.—RECOMMENDED SIZES OF WATER SUPPLY PIPES TO FIXTURES[1]
(Standard Wrought pipe)

Fixture			Number of fixtures								
			1	2	4	8	12	16	24	32	40
Water closet	Tank	g.p.m.	8	16	24	48	60	80	96	128	150
		pipe size, inches	½	¾	1	1¼	1½	1½	2	2	2
	Flush valve	g.p.m.	30	50	80	120	140	160	200	250	300
		pipe size, inches	1	1¼	1½	2	2	2	2½	2½	2½
Urinal	Tank	g.p.m.	6	12	20	32	42	56	72	90	120
		pipe size, inches	½	¾	1	1¼	1¼	1¼	1½	2	2
	Flush valve	g.p.m.	25	37	45	75	85	100	125	150	175
		pipe size, inches	1	1¼	1¼	1½	1½	2	2	2	2
Wash basin[2]		g.p.m.	4	8	12	24	30	40	48	64	75
		pipe size, inches	½	½	¾	1	1	1¼	1¼	1½	1½
Bathtub		g.p.m.	15	30	40	80	96	112	144	192	240
		pipe size, inches	¾	1	1¼	1½	2	2	2	2½	2½
Shower bath		g.p.m.	8	16	32	64	96	128	192	256	320
		pipe size, inches	½	¾	1¼	1½	2	2	2½	2½	3
Sinks[2] slop, kitchen		g.p.m.	15	25	40	64	84	96	120	150	200
		pipe size, inches	¾	1	1¼	1½	1½	2	2	2	2½

[1] W. S. Timmis, Journal Am. Soc. Heating and Ventilating Engineers, Vol. 28, p. 397, 1922.

[2] Each faucet.

Sizes based on pressure drop of 30 lb. per 100 ft.

Hot-water faucets to be disregarded when estimating sizes of risers and mains.

than the branch to an individual fixture supplied by it, and there would be little purpose in using a branch pipe larger than the service pipe unless the intermediate supply pipe leads from a storage tank.

TABLE 34.—SIZES OF BRANCH WATER-SUPPLY PIPES TO FIXTURES

Description of the fixture	U. S. Department Commerce recommendation, minimum size	Recommendation by W. S. L. Cleverdon, P. T. J. 72:867		Recommendation for sizes for different rates of pressure loss		
		Pressure 5 to 15 lb.	Pressure Over 15 lb.	$H = 0.5L$[1]	$H = L$[1]	$H = 5L$[1]
	Inches	Inches	Inches	Inches	Inches	Inches
Water closet	⅜	½	⅜	½	⅜	⅜
Urinal	....	½	⅜	⅜	⅜	⅜
Bathtub 4 ft. long	½	¾	½ to ⅝	1	¾	½
Bathtub 7 ft. long	....	....	....	1¼	1	¾
Wash basin	⅜	½	⅜	⅜	⅜	⅜
Laundry tray	½	¾ to 1	½ to ¾	½	½	⅜
Kitchen sink, small	½	⅝ to ¾	½ to ⅝	¾	½	⅜
Kitchen sink, hotel	....	....	....	¾	½	⅜
Slop sink	....	¾	½ to ⅝	¾	½	⅜
Hot-water heater	½	¾ to 1	⅝ to ¾	¾	½	½
Bidet	....	⅝ to ¾	½	⅜	⅜	⅜
Shower	....	....	....	¾	½	½
Garden hose	....	....	....	¾	¾	½
Drinking fountain	....	....	....	⅜	⅜	⅜
Water-closet flushometer	....	1¼ to 1½	1	1½	1¼	1
Pantry sink	....	½	⅜	⅜	⅜	⅜
Urinal flush valve	....	⅝ to ¾	½			
Foot bath	....	⅝ to ¾	½	½	⅜	⅜

[1] H = Head loss per unit length. L = Length

The recommended sizes of service pipes, given in Table 32, are based on the assumption that the loss of pressure in the service pipe will not exceed 10 lb. per square inch. That is, if the pressure in the public supply main is 40 lb. per square inch the pressure in the distributing pipes in the basement will not be less than 30 lb. per square inch when the normal maximum demand is being drawn.

TABLE 35.—RECOMMENDED RATES OF SUPPLY TO PLUMBING FIXTURES
(Gallons per minute)

Fixture	Recommended by				
	H. E. Babbitt	A. Buenger[1]			W. S. Timmis[2]
		Fair	Good	Excellent	
Bathtub 4 ft.	10	3	4	6	15
Wash basin	2	2	3	4	4
Laundry tray	5	4	6	8	....
Slop sink	5	3	4	6	15
Pantry sink	1	2	4	6	....
Goose-neck faucet	....	2	2	3	....
Shampoo	....	½	1	2	....
Shower bath	....	....	....	....	....
5-in. rain head	....	2	3	4	....
6½-in. rain head	....	2	3	5	....
8-in. rain head	....	4	6	8	....
8-in. tubular head	....	6	8	10	
Needle bath	....	20	30	40	
Manicure table	....	1	1½	2	

Fixture	Recommended by	
	H. E. Babbitt	W. S. Timmis[2]
Water closet	5	8
Urinal	4	6
Kitchen sink, small	5	15
Kitchen sink, large	6	15
Hot-water heater	5	
Bidet	1	
Garden hose	12	
Drinking fountain	1	
Water-closet flush valve	50	30
Shower bath	6	8

[1] Journal Am. Soc. Heating and Ventilating Engineers, Vol. 26, p. 70, 1920.
[2] *Ibid.*, Vol. 28, p. 397, 1922.

TABLE 36.—APPROXIMATE TIME IN SECONDS REQUIRED TO FILL A FIXTURE

Diameter of supply pipe, inches	Rate of discharge, g.p.m.[2]			Water-closet flush tank, capacity 4 gallons.			Bath tub 4 ft. long, capacity 50 gallons.			Wash basin, capacity 1 gallon.			Laundry tray, capacity 15 gallons.		
	H[1] = $5L$	$H = L$	$H = L/2$	$H = 5L$	$H = L$	$H = L/2$	$H = 5L$	$H = L$	$H = L/2$	$H = 5L$	$H = L$	$H = L/2$	$H = 5L$	$H = L$	$H = L/2$
⅜	8.8	4.0	2.8	27	60	85	342	750	1,071	7	15	22	105	225	330
½	14.0	6.3	4.4	17	38	55	215	480	747	4	9½	14	60	143	210
¾	38.5	17.2	12.2	6½	14	20	80	174	246	1½	3½	5	23	52	75
1	79	35.3	25.0	3	7	9½	38	85	120	¾	1¾	2½	12	25	37½
1¼	138	61.7	43.7	1¾	4	5½	22	49	69	½	1	1½	7½	14½	22½

[1] H = Head loss per unit length. L = Length of pipe.
[2] It is assumed the pressure is great enough to deliver this quantity through the faucet used on the fixture. See Table 43.

45. Illustrative Examples.—The exact computation of the sizes of intermediate pipes and risers is not practicable because of the customary complication of the pipes within a building. The most satisfactory method is to base the selection of the pipe sizes on the recommendations resulting from tests and experience. Such recommendations are presented in Table 33. The use of Table 33 is best explained by an illustrative example:

Example.—Let it be desired to determine the size of a riser pipe to serve eight water-closets, four urinals, twelve wash basins, eight bathtubs, four shower baths, and eight kitchen sinks. Table 33 shows that these numbers of fixtures call for one pipe each of the following sizes: 1¼ in., 1 in., 1 in., 1½ in., 1¼ in., 1½ in. From Table 37 it is evident that 69 ½-in. pipes are equivalent to all of these pipes, and that one 2½-in. pipe is the nearest single pipe which is equal in capacity to 69 ½-in. pipes: hence a 2½-in. riser pipe should be used, if no allowance is to be made for the improbability of the simultaneous use of all fixtures as discussed in Sec. 240.

TABLE 37.—EQUIVALENT PIPE SIZES

(The number of ½ in. pipes which will discharge as much as a single pipe of any other size for the same pressure loss)

Size of pipe, inches	½	⅝	¾	1	1¼	1½	2	2½	3	4	6	8	10
Number of ½-inch pipes with same capacity	1	1.7	2.9	6.2	10.9	17.4	37.8	65.5	110.5	189	527	1,200	2,090

Example: What size main pipe will supply two 1-in., and one ¾-in. branch pipes? Two 1-in. pipes = 12.4, ½-in. pipes, and one ¾-in. pipe = 2.9, ½-in. pipes, or a total of 15.3, ½-in. pipes. The nearest (next largest) size of pipe is a 1½-in. pipe which should be used for the main.

If the conditions for which it is desired to select a pipe are not covered in Table 33, it will be necessary to compute the size of the riser or intermediate pipe. An illustrative example will be given:

Example.—Let it be desired to compute the sizes of the service and riser pipes for the roof storage tank shown in Fig. 30 so that the rate of discharge will be 20 gal. per minute, when the pressure in the main is 42 lb. per square inch.

Solution: The height that the water must be lifted is 50 ft. which, from Table 4, is 21.7 lb. per square inch. The permissible loss of pressure in the pipe line, valves, and fittings is, therefore, the difference between 42.0 and 21.7 lb. per square inch which is equal to 20.3 lb. per square inch. The loss of head in the valves, and fittings will be assumed as 2.0 lb. per square inch leaving a net loss of 18.3 lb. per square inch in the pipe. In the 126 ft. of pipe this gives a loss of 14.5 lb. per 100 ft. From Table 16, the nearest size of pipe which will discharge 20 g.p.m. with a loss of head of 14.5 lb. per hundred feet is 1 in. in diameter.

If it is desired, after the pipe sizes have been determined from Tables 32, 33, and 34, to determine the pressure at any faucet under various conditions of flow in the plumbing system and a known pressure in the service pipe, the procedure is more complicated and is best explained by the solution of an illustrative problem:

Example.—With the pressure at S in Fig. 31 equal to 75 lb. per square inch, let it be desired to determine the minimum probable pressure at A.

The maximum demand will be assumed to occur when the following fixtures are in operation: A, C, D, F, G, and H. The total flow from these fixtures, according to Table 35, is 41 g.p.m.

In Table 16, with a flow of 41 g.p.m. the loss from S to R is $6.87 \times 0.75 = 5.15$ lb. per square inch.

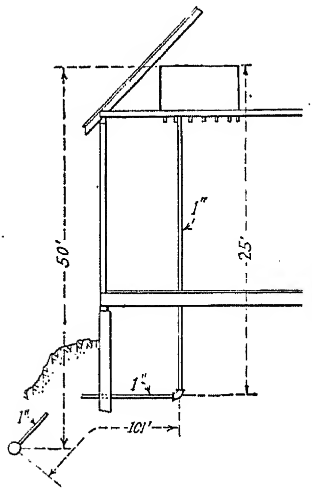


FIG. 30.

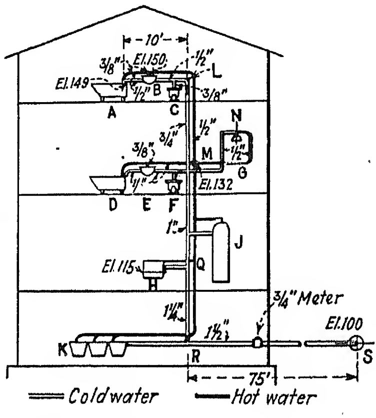


FIG. 31.—Double line is cold-water pipe. Heavy line is hot-water pipe.

The loss in the meter will be assumed as 25 lb. per square inch. The pressure at R is, therefore, $75 - 30.15 = 44.85$ lb. per square inch.

In Table 16, with a flow of 41 g.p.m. the loss from R to Q is $15.0 \times 0.15 = 2.25$ lb. per square inch.

In Table 17, with the same flow, the loss in the bend at R is negligible.

Similarly from Q to M the loss is $39.8 \times 0.17 = 6.8$ lb. per square inch.

The loss from M to L is due to a flow of 15 g.p.m. and is $28.8 \times 0.18 = 5.2$ lb. per square inch.

The loss from L to A is due to a flow of 10 g.p.m. and is $52.6 \times 0.10 = 5.26$ lb. per square inch.

The loss of pressure due to the elevation of A above S is, according to Table 4, 21.27 lb. per square inch.

The total loss from R to A, neglecting bends, is, therefore, 40.78 lb. per square inch and the pressure at A is $44.85 - 40.78 = 4.07$ lb. per square inch.

A study such as the above should be applied to all parts of an extensive plumbing system in order to make certain that the design is good and that there are no portions in which the pipes are too small.

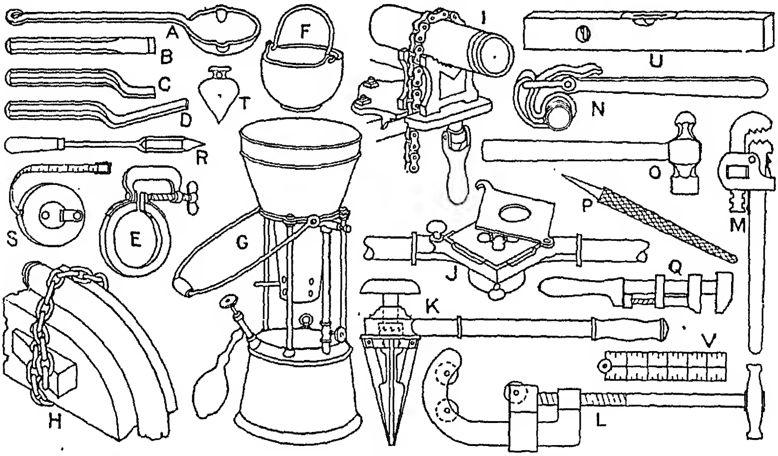


FIG. 32.—Essential tools needed in plumbing work. (*Farmers' Bull.* 1426, *U. S. Department of Agriculture.*)

A, pouring ladle; *B*, cold chisel; *C*, calking iron; *D*, yarning iron; *E*, asbestos or rubber pipe jointer; *E*, melting pot; *G*, gasoline blast furnace; *H*, home-made pipe bender; *I*, pipe vise; *J*, stock and die for threading pipe; *K*, pipe reamer; *L*, three-wheel pipe cutter; *M* 14-in. pipe wrench; *N*, brass pipe wrench; *O*, hammer; *P*, file; *Q*, monkey wrench; *R*, soldering copper; *S*, measuring tape; *T*, plumb bob; *U*, spirit level; *V*, measuring rule. These tools cost about $40.

46. Installation.—The first step in the installation of water-supply pipes for city buildings usually consists in the making of the connection to the water main with the lead goose-neck as explained in Sec. 13. The laying of the service pipe proceeds simultaneously with this. The installation of the pipes within the building follows. Some of the tools used in plumbing work are shown in Fig. 32 and a gasoline torch in Fig. 33. In small buildings the water-supply piping system includes one riser pipe for cold water and one for hot water, and the layout of the piping is simple. In apartment buildings, hotels, large residences, hospitals, etc. there may be a large number of different riser pipes. Under such circumstances simplicity of layout is essential to proper operation and maintenance. Riser pipes for differ-

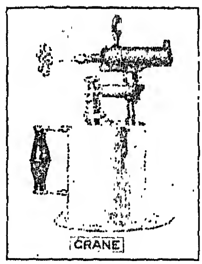


FIG. 33.—Gasoline blow torch. (*Courtesy Crane Co.*)

ent purposes may branch from a single distributing manifold in the basement, in some such manner as is illustrated in Fig. 34, or fewer and larger riser pipes may be used with more frequent branches to mains and to fixtures. The layout is dependent more on the method of operation and control than on the question of cost, which is approximately the same for either layout. Easy control by the operating engineer or janitor should be the principal consideration. Each riser pipe should be equipped with a stop-and-waste valve and, if possible, it should be labeled so that the supply to the riser can be cut off without affecting other portions of the building and the manipulation of the wrong valve can be minimized. Pipes branching from the riser main and branches

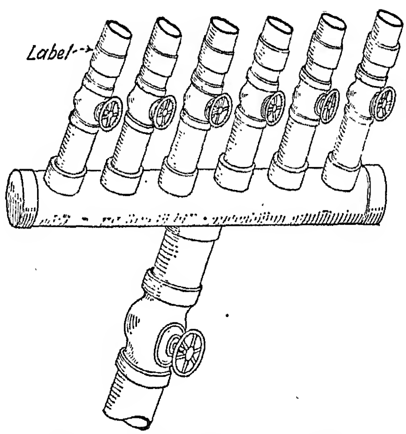


FIG. 34.—Manifold and riser pipes.

to fixtures should be equipped with valves which are labeled or whose purpose is evident by their location. Valves should be placed in an accessible and visible location.

47. Pipe Failures.—The bursting of a water pipe is usually followed by such disastrous and costly consequences to property that special care must be taken in pipe installation. Among the causes of failure can be included weak pipe or defective material, an excessive pressure in the pipes, movements of the building, freezing, and water hammer. The danger from high pressure comes as much from the wear on valves and the deterioration of valve gaskets as from the bursting of the pipe. Poor material can be avoided by purchasing material known to fulfil standard specifications. If the material is purchased from reputable

dealers and it is guaranteed to equal or better these specifications no trouble need be expected.

48. Movements of Buildings.—The movements of buildings are of such magnitude and have resulted so often in the breakage of plumbing pipes that provision should be made to avoid the damage even in the smallest building. The movements of buildings are due to the settling of the foundation, to wind pressure, to expansion and contraction resulting from temperature changes, and to the drying or moistening of lumber in the structure. No exact measure can be placed on any of these for any building but that the movements are appreciable is attested by every-day experience in frame buildings when the plaster cracks, the floor boards draw away from the base boards, doors will not close, and windows jam. Measurements in tall buildings show them to be many inches out of plumb in some cases. The Washington monument is known to sway appreciably in the wind, and a famous test on the dome of the Capitol at Washington has shown it to move 6 in. between the hottest and coldest parts of the day.

As it is not possible to prevent such movements, the plumber provides for them in the installation of his pipes by the use of expansion joints, the location of the pipes, and in other ways which are discussed in the sections pertaining to the installation of pipes.

49. Shrinkage of Lumber.—Lumber in drying shrinks appreciably, the greater change occurring across rather than along the grain. The average values for cross-grain shrinkage are shown in Table 38. Lumber will swell and shrink repeatedly as it absorbs moisture and moisture evaporates from it.

50. Expansion of Pipe.—The expansion of water-supply and drainage pipes, particularly hot-water pipes, is sufficient to require attention in design. The coefficients of expansion of the various materials used in pipes are given in Table 39.

The movement in a brass hot-water pipe 100 ft. long when the temperature changes from 40 to 212° F. is equal to $0.0000104 \times 100 \times (212 - 40) \times 12 = 2\frac{1}{8}$ in., approximately. It is evident that the movements are appreciable and must be cared for. This can be done by the use of swing joints in threaded pipe or with flexible bends, as shown in Fig. 35. Supports in which the pipe can move should be used. Many such supports are illustrated in Fig. 36. Expansion joints should be used in hot-water pipe lines at least every 50 ft. and the pipe should be well supported

TABLE 38.—APPROXIMATE SHRINKAGE OF TIMBER IN DRYING

Timber	Transverse shrinkage	
	Per cent	Approximate size to nearest one-sixteenth of an inch of a dry timber which was 2 by 10 in. when green
Light conifers (soft pine, spruce, cedar, cypress)	3	2 by $9\frac{11}{16}$
Heavy conifers (hard pine, tamarack, yew), honey locust, box elder, old oaks	4	2 by $9\frac{9}{16}$
Ash, elm, walnut, poplar, maple, beech, cherry, sycamore, and black locust	5	$1\frac{15}{16}$ by $9\frac{1}{2}$
Basswood, birch, chestnut, blue beach, young locust	6	$1\frac{15}{16}$ by $9\frac{3}{8}$
Hickory, young oak, red oak	10	$1\frac{7}{8}$ by 9

The longitudinal shrinkage of all timber is usually less than $\frac{1}{10}$ per cent.

TABLE 39.—COEFFICIENT OF EXPANSION OF PIPES

Metal	Coefficient of expansion per degree Fahrenheit	Change in length of 100 ft. of pipe for 100° F. change of temperature, inches
Wrought iron	0.00000686	$\frac{1}{16}$
Steel	0.0000061	$\frac{1}{16}$
Cast iron	0.0000059	$\frac{1}{16}$
Copper	0.0000095	$\frac{3}{32}$
Brass	0.0000104	$\frac{7}{64}$
Lead	0.0000159	$\frac{5}{32}$

midway between expansion joints. At the expansion joints the pipe should be free to change in length.

Expansion in cast-iron pipe is usually not provided for because of its relatively low coefficient of expansion and the conditions of its installation. When used as a cold-water supply pipe the changes in temperature are slight and when used as a drainage pipe in a building the normal changes of temperature are within

40 to 50° and the building and pipe are subjected to the same changes in temperature so that the building movements due to temperature changes approximate those of the drainage pipes. The increase in length of 50 ft. of cast-iron pipe with a 50° change of temperature will be about 3/16 in.

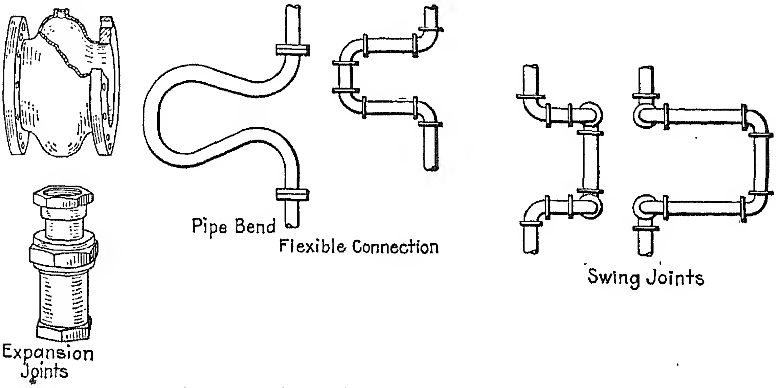


Fig. 35.—Provisions for expansion in pipe.

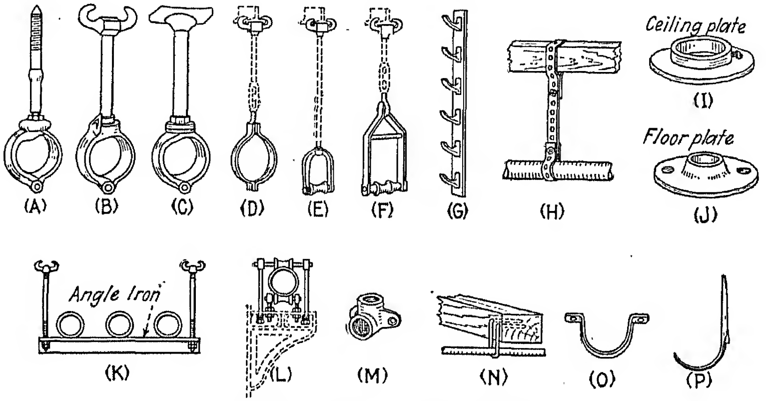


Fig. 36.—Types of pipe supports.

In order to minimize movements of drainage pipes due to temperature changes, the discharge of hot wastes into them is usually prohibited.

51. Pipe Supports.—Breaking of the pipe from movements of the building can be avoided by hanging the pipe in supports which will permit some motion between the pipe and the support. This is possible in all of the supports shown in Fig. 36, except *M*, which

is known as a drop elbow. The pipe is threaded into it and it is screwed to its support. The pipe should be adequately supported to prevent sagging but it should not be rigidly attached to the building. Since pipe may start vibrating in the supports, some form of soft material, such as felt, should be used to stop the motion or to deaden the sound.

Lead pipe should be supported for its entire length whenever sagging is possible. Cast-iron and vitrified clay pipe, when laid horizontally or slightly sloping, should be supported at each joint, and wrought, brass, or copper pipe when horizontal, or approximately so, should be supported at least every 10 ft.

Long, vertical lines of pipe are usually supported at each floor, the support being so arranged that the settlement of the building will allow the pipe to lift out of the support, as illustrated in Fig. 37. A joint, or coupling, is shown at the support, as is desirable. Pipes passing through floors, particularly through concrete floors, should do so through loose sleeves. The pipes should not be encased in the concrete or plaster.

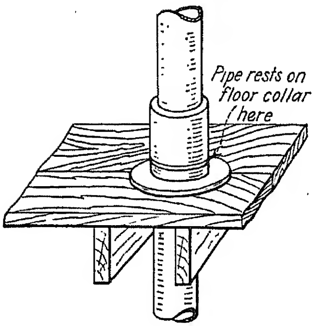


FIG. 37.—Support for a vertical pipe.

52. Pipe Slopes.—It is desirable to place water-supply pipes so that in case the water is to be shut off the water will drain from the pipes. For this purpose so-called "horizontal" pipe should be placed only approximately horizontal, the slope being towards the stop-and-waste valve or other point of drainage. Where it is not possible to continue the slope in one direction, drain cocks or plugs should be inserted in the line. It is far more desirable, however, to install the entire supply pipe so that it will drain to one point.

53. Pipe Location.—In the location of the pipe in the floors, walls, and partitions of a building, the accessibility of the pipe should be considered. It is undesirable to install a pipe so that much damage to the building will result from an attempt to gain access to the pipe. A good plan is to group pipes in "runs" within the walls. These are vertical shafts to which access should be had through doors or easily removed panels. The shafts should have horizontal partitions at reasonable intervals

to prevent the shaft from acting as a chimney in the event of fire. The pipe runs should be lined with waterproof material to prevent moisture from penetrating the walls, and they should be provided with "safe" drains at the bottom to catch leakage or water of condensation which may collect on the colder pipes in humid weather. Hot-water pipes, cold-water pipes, drainage pipes, gas pipes, electrical conduits, etc. can be grouped in a run. It is undesirable to place hot and cold pipes close together as the temperature of one is likely to affect the temperature of the other. The most objectionable effect will be the heating of the cold-water supply. It is desirable that the outside of the pipe run should be paneled or otherwise covered so as to be easily and inexpensively uncovered and re-covered.

54. Pipe Connection.—Connections between pipes are made with threaded couplings, threaded unions, flange unions, and calked joints in bell-and spigot pipe. The methods and materials used in making joints are described in Secs., 158 to 166. The location of pipe joints and the fitting together of pipes require the exercise of ingenuity in which skill and experience are helpful.

55. Bell-and-spigot Joints.—In roughing-in a new piece of work the pipe fitter must be careful that he does not so install the piping that one piece of bell-and-spigot pipe or a fitting must

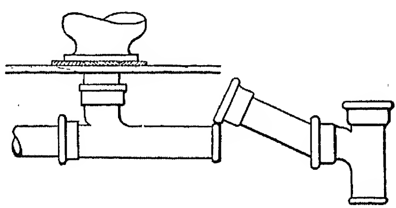


Fig. 38.

be used to connect two pieces already in place. The remaining piece cannot be connected, as shown in Fig. 38. Bell ends should be pointed upwards or horizontally and they should be kept away from surrounding obstructions so as to make calking easier.

In some cases it is necessary to insert a fitting into an existing line of pipe, as shown in Fig. 39*A*, the position of the new fitting being shown in dotted lines. The first step in inserting the fitting is to melt the lead from joints *A* and *B* and to smash the pipes *J*. Then calk in the proper length of pipe *C* (Fig. 39*C*). Pieces *E*, *F*, and *G*, cut to proper length, are then slipped loosely into

place. Piece E is a Sisson Insertable Joint which has a hub of double the ordinary depth. Piece E is then calked to C. G and F are pulled up into place, and all joints are calked.

Another method of making the connection would be with a saddle fitting, as shown in Fig. 40, but the use of saddle fittings is not recommended because of dangers from leakage and clogging.

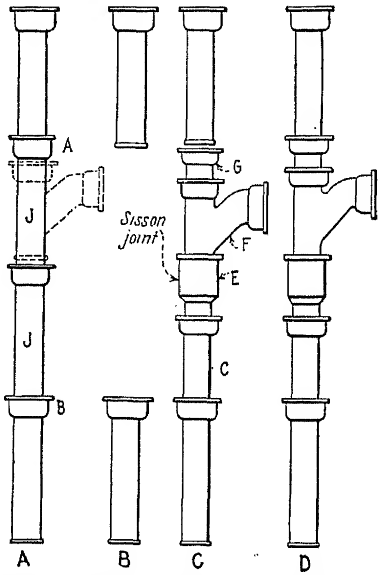


FIG. 39.—Method of inserting a Sisson joint.

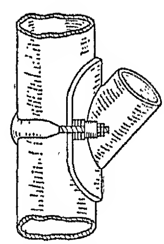


FIG. 40.—Saddle fitting.

56. Threaded Joints.—Joints in threaded pipes are made with couplings such as are shown in Sec. 7, Appendix I. Where two pipes already in position are to be joined the connection is made in any one of three ways: by means of a box union, a flange union, or a right-and-left threaded pipe coupling. In joining a box or a flange union the method is evident from the figures.

In making a right-hand and left-hand coupling connection the positions of the couplings and pipes are shown in Fig. 41. The coupling at the left has a right-handed thread, and that at the right a left-handed thread. The number of threads cut on the pipes should be just sufficient to make the couplings tight when turned up. Couplings and unions should be used generously in

pipe lines to permit taking down portions of the pipe without dismantling the whole system or large portions thereof.

57. Dimensioning and Measuring Pipes.—In dimensioning pipe lines on drawings the actual distance along the center line of the pipe is shown. In cutting pipe to fit such dimensions, care and knowledge of standards are necessary.

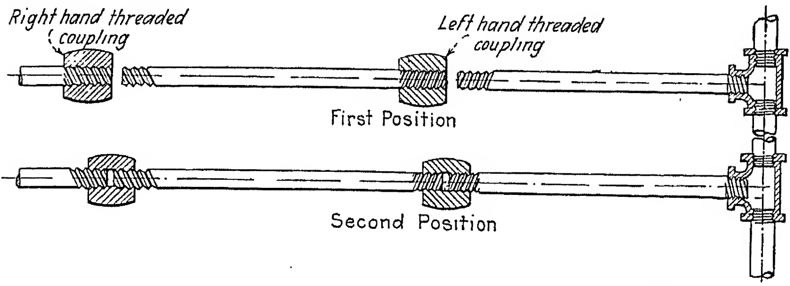


FIG. 41.—Right-handed and left-handed coupling connection.

In cutting pipe where threaded joints are to be used the length can be determined from the formula,

$$L = D - (F_1 + F_2 - 2T).$$

The significance of the letters is shown in Fig. 42. Standards for sizes of fittings are given in Appendix I, Tables 119 and 120.

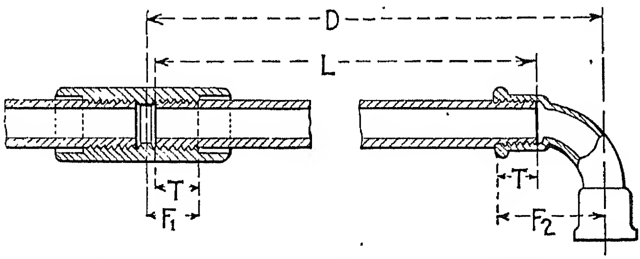


FIG. 42.—Pipe measurements. Threaded joints.

Example.—As an illustrative problem let it be assumed that in the above sketch D = 7 ft. 3½ in., that the pipe is 2½ in. standard wrought pipe, and that it is connected into a malleable 90-deg. elbow and a wrought coupling.

Then from Table 119 the value of $F_1 = 1\frac{7}{16}$ in., and from Table 120 $F_2 = 2\frac{11}{16}$ in., and from Table 117 $T = 1\frac{1}{2}$ in. The value is
L = (7 ft. 3½ in.) − ($1\frac{7}{16}$ in. + $2\frac{11}{16}$ in. − 2 × 1½ in.) = 7 ft. 2⅜ in.

When threaded pipe is to be used with flanged fittings a flange must be screwed onto the end of the pipe. The cut length of

the pipe will then be 1/8 to 1/4 in. less than $D - F_2$ as shown in Fig. 43.

If, as before, D = 7 ft. 3½ in., then, from Table 105, F_2 = 5 in., and, therefore, L = 6 ft. 10¼ in.

In cutting and fitting bell-and-spigot pipe the problem is again slightly different, as shown in Fig. 44. The dimensions

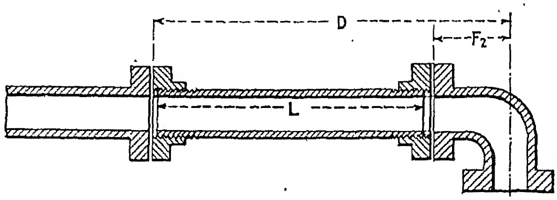


FIG. 43.—Pipe measurements. Flanged joints.

of the pipe and fittings, as shown above, are given in Sec. 5 of Appendix I. The difference between the sum of the known dimensions of uncut pipe and fittings and the dimensions 7 ft. 3½ in. between center lines will give the length of the cut pipe to be 11½ in. as shown in the figure.

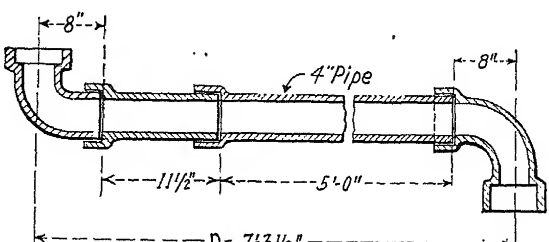


FIG. 44.—Pipe measurements. Bell and spigot joints.

The determination of the length of pipe in angular directions sometimes presents problems that can be solved with precision only with a knowledge of geometry and trigonometry, but for which a satisfactory solution can usually be reached by rule of thumb. Where a precise result is not desired the use of Table 40 will usually be found satisfactory.

For example, the following problem will be solved by the application of the principles of geometry and by the use of Table 40.

TABLE 40.—LENGTH OF PIPE MEASURED ON AN ANGLE
(For sketch see Fig. 45)

Angle α degree of offset	Number of inches to add to each foot of length A to get length L	Number of inches to add to each foot of length B to get length L
$5\frac{5}{8}$	$110\frac{3}{8}$	$0\frac{3}{32}$
$11\frac{1}{4}$	$37\frac{3}{8}$	$0\frac{1}{4}$
$22\frac{1}{2}$	$19\frac{5}{16}$	1
30	12	$1\frac{7}{8}$
45	5	5
60	$1\frac{7}{8}$	12

Example.—Let it be required to join two vertical lines of pipe which are 18 in. apart by a pipe at an angle of 45 deg. using galvanized malleable fittings as shown in Fig. 45. What length of pipe should be cut to fit between the two vertical pipes?

From the geometrical relations of the figure the distance D is the hypothenuse of a 45-deg. right triangle whose base is 18 in., hence the length $D = \sqrt{(2)\ (18)^2}$ or $25\frac{1}{2}$ in. The length L is then determined as shown previously, and in this case will be $22\frac{1}{2}$ in.

The same problem will now be solved by the use of Table 40. It is evident from the table that for every foot of distance between the parallel pipes the length of D should be 17 in., hence, in this case, the length D should be 1.5×17 or $25\frac{1}{2}$ in.

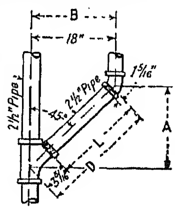


FIG. 45.—Pipe measurements on an angle.

58. Cleanout Location.—Cleanouts are desirable on pipe lines in order that clogging materials can be removed. They are seldom used on water-supply pipes but are frequently used on drainage pipes. On the former a satisfactory type of cleanout consists of a plugged T, cross, or Y, somewhat as shown in Fig. 46. Cleanouts for drainage lines are discussed in Sec. 140.

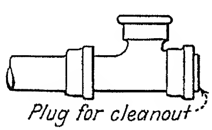


FIG. 46.—Plugged tee for cleanout.

59. Leaks.—Leaks may occur in a pipe line within the walls, or in the ground, or elsewhere, in such a manner that water escapes into the ground or into the sewer without detection, or the water may escape into the building with resultant damage. In either case the financial loss may be large. The cost of the loss of water through leaky pipes has been variously esti-

mated. The principal factors controlling this are the size of the hole through which the leak is occurring and the pressure of the water. Under normal conditions it can be estimated that the losses are as shown in Table 41.

TABLE 41.—APPROXIMATE WASTE OF WATER THROUGH LEAKS

Size of opening, inches	Gallons per day	Gallons per month	Cost per month at 10 cts. per 1,000 gal.
1/4	12,000	360,000	$36.00
3/16	8,000	240,000	24.00
1/8	4,000	120,000	12.00
1/16	1,000	30,000	3.00
1/32	400	12,000	1.20

The location of a leak within the walls or floor of a building requires experience and ingenuity, on the part of the plumber, which should be supplemented by a thorough acquaintance with the piping installation within the building. Usually it is easy to locate a leak in a building but sometimes it is very difficult because, unfortunately, water does not always appear near the point from which it is escaping from the pipe. The tearing out of walls and floors is expensive and can sometimes be avoided by the use of instruments, such as Darley's Leak Locater, which depend on the principle of the electric coil and magnetic field for the location of the pipe. In costly buildings *X*-ray pictures have been used to locate pipes and leaks.

The location of leaks in underground pipes is made possible by various methods some of which are described in an article on "The Location of Leaks in Underground Pipes," in the *Journal American Waterworks Association*, July, 1920, page 589. The methods discussed in this article include: (1) direct observation of running water or melted snow or green grass during a drought; (2) the use of test rods thrust into the ground to find moisture; (3) sound-detecting instruments either transmitting the sound directly or electrically amplified. These instruments include the aquaphone, waterphone, dectaphone, sonograph, sonoscope, geophone, and Darley's Leak Locater; (4) the utilization of the principles of water hammer; (5) the utilization of the principles

of the hydraulic gradient; (6) the use of chemicals to measure water movement; (7) volumetric displacement to measure movements; (8) the use of blueing or air in submerged pipe.

60. Repairs of Leaks under Pressure.—After a leak has been discovered and it is so located that the water cannot be shut off, if it is possible to stop the leak temporarily, the water in the pipe on the pressure side of the leak can be frozen by the use of a freezing mixture and the repairs made while the pressure is cut off by the plug of ice.

Sometimes a valve can be inserted on the threaded end of a pipe while water is flowing from the pipe by screwing the valve on the end of a piece of pipe about 6 to 8 ft. long, opening the valve wide, and then screwing it into position handling it with the long piece of pipe. When the valve is in position it can be closed, the piece of pipe removed, and further repairs made with the pressure shut off.

61. Water Hammer.—Water hammer is caused by the sudden stoppage of the flow of water in a pipe or other closed conduit. The most probable causes of water hammer are the sudden closing of self-closing faucets, quick-closing valves, or other methods of quickly shutting off the flow of water. The effect of water hammer is a sudden increase in the pressure which may be accompanied by a knocking sound in the pipe. The intensity of the noise is not a measure of the pressure produced. Water hammer is not a series of sudden blows but is a series of pulsations of pressure above and below normal, the periodicity of the pulsations depending on the size and length of the pipe and other factors.

If a pressure gage is placed close to a quick-closing valve on a pipe line in which the pressure when the valve is closed is N lb. per square inch and the valve is slowly opened and then very suddenly closed the pressure will be seen to jump above N and remain there for some time; it will then suddenly drop below N and remain there for some time. The fluctuations will continue, each change being less than the preceding, until the waves of pressure are damped out by friction. The time that the pressure gage remains at the high or low points is determined by the time it takes the pressure wave to pass to a point of relief and to return to the gage. The velocity of the wave is equal to that of sound in water which is about 4,800 ft. per second.

Pressures which may be produced have been computed from the expression

$$P_1 = 0.027\frac{lv}{t} + p_1 - p_0$$

$$P_2 = 63v + p_1 - p_0$$

in which

P_1 = the pressure in pounds per square inch when t is greater than $0.000428l$

P_2 = the pressure in pounds per square inch when t is less than $0.000428l$

p_0 = the static pressure in pounds per square inch when there is no flow.

p_1 = the static pressure in pounds per square inch when there is some flow.

v = the velocity of flow in feet per second.

l = the length of the pipe in feet.

t = the time of closing the valve in seconds.

The results of some computations are given in Table 42.

TABLE 42.—PRESSURE, ABOVE NORMAL, RESULTING FROM WATER HAMMER
(Pounds per square inch)

Velocity, feet per second	Maximum possible pressure	Valve closed in 0.1 sec.		Valve closed in 0.5 sec.		Valve closed in 1.0 sec.		Velocity, feet per second	Maximum possible pressure	Valve closed in 0.1 sec.		Valve closed in 0.5 sec.		Valve closed in 1.0 sec.	
		100 ft. of pipe	10 ft. of pipe	100 ft. of pipe	10 ft. of pipe	100 ft. of pipe	10 ft. of pipe			100 ft. of pipe	10 ft. of pipe	100 ft. of pipe	10 ft. of pipe	100 ft. of pipe	10 ft. of pipe
1	59	27	3	13.5	1.4	0.27	0.027	7	413	189	19	95	9.5	1.9	0.189
2	118	54	5	27	2.7	0.54	0.054	8	472	216	21.5	108	11	2.2	0.216
3	177	81	9	40.5	4.1	0.81	0.081	9	531	243	24	122	12	2.4	0.243
4	236	108	11	54	5.4	1.10	0.110	10	590	270	27	135	13.5	2.7	0.270
5	295	125	12.5	67	6.7	1.25	0.125	15	885	405	41	202	20	4.1	0.405
6	354	142	14	71	7.1	1.40	0.142	20	1,180	540	54	270	27	5.4	0.540

Methods of avoiding or curing water hammer include: the use of air chambers, the use of mechanical compensating devices, and the use of slowly-closing faucets. The use of pressure-reducing valves or the installation of large-sized pipes is also helpful.

Air chambers should be installed near to the valve which is causing the water hammer, and, if possible, in a vertical position over a riser pipe, as shown in Fig. 47.[4] The air chamber should

have a capacity of at least 1 per cent of the total capacity of the pipe line in which the water hammer is occurring. The purpose of placing the chamber in the position shown in the figure is twofold: first, because air in the riser pipe will be trapped in the chamber, thus aiding in keeping the chamber full of air; and second, it will receive the full thrust of the pressure from the vertical pipe line and will thus be more effective in its operation. Provision should be made for renewing the air in the chamber. This can be done by the use of a stop-and-waste valve and a pet cock or larger valve, as shown in Fig. 47.

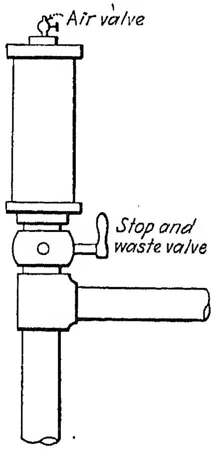


FIG. 47.—Air chamber to control water hammer.

A mechanical compensating mechanism operates on a similar principle to the air chamber except that the cushioning effect is supplied by a coiled spring within the chamber instead of by compressed air. Such a mechanism usually requires no attention for maintenance.

The installation of a pressure-reducing valve on the supply line to the source of the water hammer will result in a reduction of the velocity of flow in the pipe. It will be seen from the formulas for water-hammer pressure that the intensity of pressure varies directly with the velocity of flow in the pipe. The use of large-sized pipe will also cut down the velocity of flow but to determine the exact size necessary to reduce the water hammer to any particular amount would require tests of an existing installation and knowledge of mechanics and hydraulics.

62. Frozen Pipes.[5]—The freezing of water in pipes is due to too long an exposure of the water in the pipe to a temperature below 32° F. It is to be noted that both time and temperature are factors in the freezing of pipes, because it takes time to remove sufficient heat from the water and its surroundings. Plumbing will sometimes pass through severe cold snaps without freezing, whereas a milder temperature of longer duration, possibly accompanied by high winds, will have a more serious effect. Unfortunately when water freezes it expands with a force which cannot be resisted by any pipe manufactured. Water expands on freezing about one-twelfth of its volume, *i.e.* 12 cu. ft. of

water will become 13 cu. ft. of ice. This increase in volume usually causes the bursting of the pipe.

The occasional failure of pipes to burst on freezing is explained by the conditions under which freezing has taken place. In order to burst a pipe the freezing water must be confined. If there is no confinement the expanding ice pushes along the pipe without damage. This will explain why a pipe in a warm place may burst when freezing occurs in the basement. The expanding ice exerts a high pressure which finds the weakest spot in the line. This may not be near the seat of the trouble. There is no value in trying to thaw a pipe by heating it near the point of bursting. The pipe must be thawed where the ice has formed.

The freezing of pipes can be avoided by locating them in inside partitions and in other warm and protected places; by keeping the building warm when water is in the pipes; and by draining the water out of the pipes if the building is not to be heated. Covering the pipes with materials which conduct heat poorly is of great aid. Such materials as hair felt, wool felt, asbestos, asbestos air-cell, magnesia, cork and sawdust are suitable. Mineral wool has proven unsatisfactory because it packs and disintegrates.

The thawing of frozen pipes is accomplished by the use of gasoline torches applied to the bare pipe where it is frozen; wrapping the pipe in rags and pouring on hot water; blowing steam on the pipe; and in other ingenious but usually messy ways, or by the use of electricity which is certain, quick, neat, and inexpensive.[6] In any process of thawing care should be taken not to crack the pipe by too sudden application of intense heat. During the process of thawing the pipe should be left open to start a flow of water as soon as possible. A strong flow of water will remove ice more rapidly than the ordinary application of heat.

Thawing frozen pipes by electricity* requires that sufficient current (amperes) be forced through the pipe to raise its temperature above the freezing point. The amount which the temperature is raised depends only on the amount of current flowing (amperes, not volts) and the cross-sectional area of the pipe or, in other words, the resistance of the pipe per foot of length. A current of 100 amp. will heat 1,000 ft. of ½-in. pipe just as rapidly as it will 10 ft. The difference is that it will require one hundred times as much voltage to force 100 amp. through 1,000 ft.

* From notes prepared by Prof. W. J. Putnam for the Plumbing Short Course at the University of Illinois, 1922.

as it will to force the same current through 10 ft. of pipe, and the power used varies accordingly.

It has been found by test that for thawing ordinary house plumbing, consisting mainly of ⅜- to ¾-in. pipe, there should be available a current of 100 to 200 amp. at from 3 to 10 volts, the higher current (amperage) being used on the larger pipes regardless of length and the higher voltage being required for the longer runs regardless of size.

The current used may be safely carried by the ordinary house wiring. The cost of power is very small, as the time of thawing is usually short.

Using the full rating of the transformer for 6 min., which is more than has ever been required in any of the tests, would use only 2 cts. worth of power at the ordinary rate of 10 cts. per kilowatt hour. The dangers of operation are no more than using a flatiron or an electric fan. The transformer may be plugged into the electric circuit by an extension cord just as is any other electrical appliance. The voltage on the secondary side is entirely harmless. It is so low that a good coat of paint or enamel will prevent its flowing from or into the pipe, and the hands may be safely laid across the terminals and no sensation of shock experienced.*

63. Air Binding.—Air binding is caused by the collection of air in the top of loops or inverted traps in a pipe line. The air may accumulate to such an extent that the pressure necessary to force the water over the bends is greater than the available pressure, thus shutting off the flow of water in the pipe. The head of water may sometimes be sufficient to force some water over the loops but the flow will be restricted. The condition which results in air binding is illustrated in Fig. 48. In the condition illustrated in the figure the flow will be stopped if $h_1 + h_2$ is materially greater than h_3. If $h_1 + h_2$ is approximately equal to h_3 a small amount of water will flow over the loops and from faucet No. 1 when it is opened, without affecting the existence of the air lock.

Air binding can occur only where there are bends in a pipe line in which air can accumulate and where there is but a small pressure available to force water through the pipes. It will probably occur on the top floor of a building supplied by a roof tank or by a tank on the top floor. Gas or air is more likely to

* Transformers for the purpose are sold by the General Electric Company, 100 Woodlawn Ave., Pittsfield, Mass. These are known as the G. E. Wayne Pipe Thawer.

accumulate in top-floor pipes, and the available pressure head to force the water past the stoppage is smallest on the top floor.

Air binding can be prevented by avoiding the installation of inverted traps in the pipe and by the provision of sufficient pressure to overcome the lock if the binding occurs. It can be cured by placing an air valve or a faucet at the top of the inverted trap through which air can escape from the pipe.

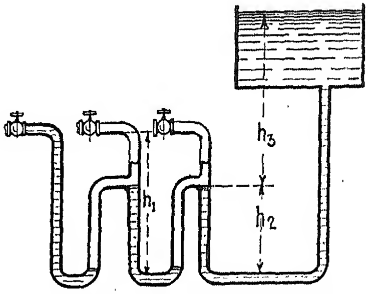


FIG. 48.—Diagram illustrating air binding.

64. Tests.—Tests of the water-supply pipes should be made after roughing-in and before walls, ceilings, and floors are completed. The tests are made by closing all openings and turning on the water pressure. The pressure maintained during the test should be 50 to 100 per cent higher than the maximum pressure to which it is expected that the system will be subjected. The increased pressure can be obtained by attaching a hand force pump to the plumbing system and raising the pressure the required amount. The amount of additional water required by the force pump after the pipes are filled is slight, usually less than 5 gal. The force pump should be equipped with a pressure gage. After the required pressure has been reached and the pump has stopped, a drop in the pressure will indicate a leak in the system. The pipes are then inspected by eye and ear for the leak. A similar procedure is followed after the fixtures have been installed and the plumbing system completed. Tests on the water-supply system are seldom required in plumbing codes but they should be made in the interest of the owner and to assure good work on the part of the contractor.

References

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3. "Location of Leaks in Underground Pipes." *Jour., Am. Waterworks Assn.*, p. 589, July, 1920.
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CHAPTER V

VALVES AND FAUCETS

65. Definitions and Descriptions.—Valves,[1] faucets, and stop cocks are used for controlling the flow into, through, and from pipes. The use of the terms "valve," "faucet," "cock," "bibb," "stopper," "tap," etc. has created such confusion that there is an attempt to confine them all to one term. The proper name, according to the Brass Manufacturers' Association,[1] is *faucet*. This does not seem to cover all of the possibilities, however, so that the terms "valve," "faucet," and "cock" have been used in this text with the special meanings given in Appendix II on definitions.

Valves are made of malleable iron, plain or galvanized; of brass, rough, polished, plain or nickel plated; of bronze; of cast iron with plain, brass, or bronze parts; and of less corrodible metals for special conditions. Faucets for household installations are usually made of brass, plain or nickel plated, although there is a tendency to use faucets made of a white alloys as these stand polishing better than nickel-plated brass. Practically all except very special types of valves are available in all pipe sizes up to and including 12 in. Gate valves are made with bell-and-spigot, flanged, or threaded ends in all sizes up to 12 in., and in larger sizes with bell-and-spigot or flanged ends. Other types of valves are made with threaded ends and some valves are made with either threaded or flanged ends. Dimensions of valves are not the same for all manufacturers and no generally recognized standard of valve dimensions has been adopted. Practically all threaded valves are equipped with inside threads, and some threaded valves are equipped with one outside and one inside thread. Valves can be obtained with both ends threaded with outside threads. Valve handles are made of the same materials as the valves, or they may be made of wood or lined with wood, porcelain, or other material. Handles are made in the shape of wheels or as straight shafts. Various types of handles are illustrated in Fig. 66.

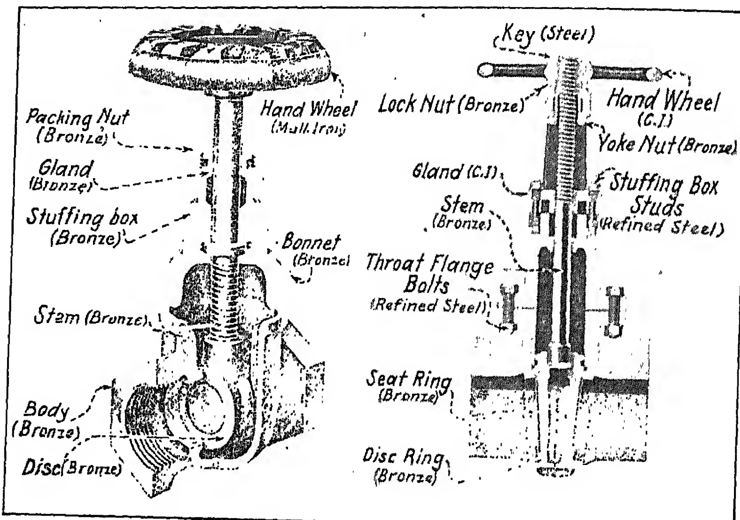
"Faucet," "bibb," "cock," etc. are terms used synonymously with *valve* but they are more especially applicable to water-supply

outlets from plumbing fixtures. Various styles of such outlets are shown in Fig. 66. They are generally available in all styles with either inside or outside threads, in sizes from ⅜ to 1 in. The loss of pressure and discharge rates through various types of faucets are shown in Table 43.

TABLE 43.—RATES OF DISCHARGE FROM FAUCETS

Manufacturer	Type and condition of faucet	Test number	Discharge in g.p.m. for pressure on faucet of: Inches of water	Pounds per square inch		
			6	5	30	90
Wolverine	¾ in. compression sink faucet, wide open	1	1.8	8.1	20.0	33.4
	¾ in. compression sink faucet, three-fourths open	1	1.8	......	19.5	32.8
	¾ in. compression sink faucet, one-half open	1	1.8	7.6	19.0	32.9
	¾ in. compression sink faucet, one-fourth open	1	1.5	7.0	17.4	29.9
Wolverine	½-in. compression sink faucet, wide open	2	1.4	6.0	14.8	24.5
Mueller	½-in. ground-key sink faucet, wide open	5	2.2	9.5	23.4	36.4
Mueller	½-in. self-closing compression faucet, wide open	8	0.6	2.6	6.8	11.7
Mueller	½-in. compression laundry-tray faucet, wide open	12	1.4	6.3	17.3	25.3
Mueller	Compression wash-basin faucet, wide open	13	1.7	5.0	11.9	21.3
Mueller	1-in. ground-key sink faucet, wide open	15	7.2	30.7	78.9	118.8
Mueller	1-in. compression sink faucet, wide open	16	3.5	12.7	39.9	64.8
Wolverine	Combination laundry-tray faucet Catalog No. 640. Both outlets open	17	2.3	9.6	22.4	38.6
Wolverine	Combination laundry-tray faucet Catalog No. 640. Either hot or cold, wide open	17	1.4	6.1	14.4	24.8
Wolverine	Combination compression bathtub faucet. Both sides open. Nozzle attached Catalog No. 635	18		8.0	20.4	34.4
Mueller	Combination compression sink faucet with swinging nozzle. Both sides open	21	0.97	4.6	12.2	21.4
	Combination compression sink faucet with swinging nozzle. Hot open, cold closed	21	0.72	3.3	8.6	15.1
	Combination compression sink faucet with swinging nozzle. Cold open, hot closed	21	0.69	3.1	8.2	14.5
Mueller	Combination compression high gooseneck pantry-sink faucet, No. 3822. Hot and cold open	22	0.88	4.6	11.6	20.9

All valves are made tight against the flow of liquid or gases through them either by a gasket of softer material than the valve or by a ground-faced metal-to-metal seat. The gasket is pressed tightly against the seat by the screwing down of the valve stem. Where the valves are controlled by handles which must be turned or lifted, soft packing is usually necessary around the valve stem to prevent leakage. This packing is held in place by a compression cup or gland which is screwed down on to it. The packing glands are shown in the various illustrations of valve sections. This packing can be renewed in some valves without shutting off



Non-rising stem Outside screw and yoke

FIG. 49.—Sections through two types of gate valves.

the liquid or gas controlled by the valve but it is usually necessary and safer to shut off the pressure on the valve before the packing is removed.

The three types of valves commonly used on plumbing systems are gate valves, globe valves, and ground-key valves. No standard dimensions for any of these valves have been adopted by any recognized authority. Where roughing-in dimensions are desired, they must be obtained from the manufacturer. The special features of the different types of valves will be discussed in the following sections. The losses of pressure through various types of valves are shown in Tables 18 to 22, inclusive.

66. Gate Valves.—Two types of gate valves are shown in Fig. 49. The mechanism consists of two ground-faced metal disks which fit against a double ground-faced metal seat. The valve is closed by turning the handle attached to the stem which forces the disk down on to the seat. The non-rising stem is the type commonly used on small pipes. A gate valve is a very satisfactory type of valve because of the full waterway opening provided and the absence of packing around the valve seat. The valve may be placed upon the pipe in any position and with either face against the pressure. Packing is required about the valve stem, however. This is kept in place by means of the stuffing box, or gland, shown in Fig. 49. A quick-closing gate valve, illustrated in Fig. 50, can be completely closed or opened by a quick, short movement of the valve handle.

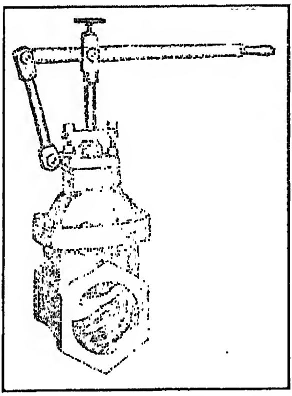


Fig. 50.—Quick-closing gate valve.

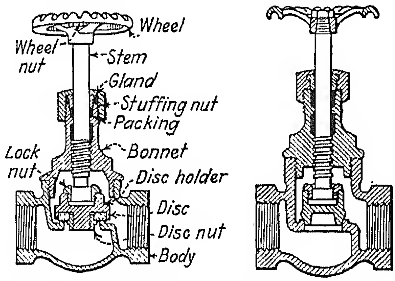


Fig. 51.—Section through globe valve.

67. Globe Valves.—Two globe valves are illustrated in Fig. 51. The gasket or disk is forced down upon the seat of the valve by turning the handle, thus shutting off the flow of liquid or gas. If the valve leaks at this point the gasket must be replaced or the packing around the stem of the valve must be renewed. This is done by removing the bonnet after the pressure has been shut off in the pipe, and slipping a new gasket into place or replacing the packing. Globe valves are made with a ground-faced metal disk fitting against a ground metal seat as shown in Fig. 51. An objection to the use of this type of valve is the difficulty of stopping leaks when once started but they are more suitable on steam and hot-water lines than valves depending on gaskets for their tightness.

In placing a globe valve on a pipe it is desirable, but not essential, that the valve be placed so that the flow is upwards through the orifice and that the disk is screwed down against the pressure in shutting the valve. Globe valves are used to a great extent on plumbing systems in spite of the fact that the loss of pressure through them is higher than for many other types of valves available. This loss of head is due to the small and tortuous passages through the valve. Globe valves are not suitable on hot-water and steam pipes unless a special type of packing is used in them. An added objection to their use is the impossibility of draining the pipes because of the trap caused by the valve seat, which rises nearly to the center of the pipe, unless the valve is placed on its side.

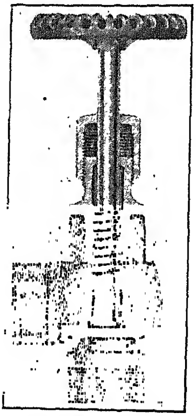


FIG. 52.—Section through an angle valve.

An angle valve, shown in Fig. 52, is a special type of globe valve which does away with some of the objections to the straight globe valve and is suitable for use on a 90-deg. change of direction in the pipe. The opening through an angle valve is usually larger than through the straight globe valve, the passage through the valve is straighter and it offers no obstacle to the drainage of the pipe. Angle valves are found useful in close work where but little space is available. Their use replaces one fitting on a pipe line.

68. Ground-key Valves.—A ground-key valve is shown in Fig. 53. The principal advantages of this type of valve include the clear and unobstructed waterway offered when the valve is opened, the absence of soft packing to wear out, its suitability for hot water, and the fact that it can be completely and quickly opened by a one-quarter turn of the handle. There are two principal objections to the valve: one arises from the possible water hammer which may result from the too quick manipulation of the valve; and the other is that when the key becomes badly worn the valve may leak or jam and it is difficult to make repairs.

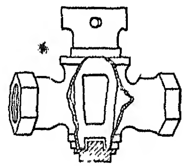


FIG. 53.—Section through a ground key valve.

Such valves are used almost exclusively as corporation or curb cocks and are quite popular on faucets for kitchen sinks.

69. Check Valves.—Check valves are used to prevent a backward or reverse flow through a pipe line. They may be installed on the discharge end of a pump to prevent back flow through the pump when it is stopped, or a back-water valve may be

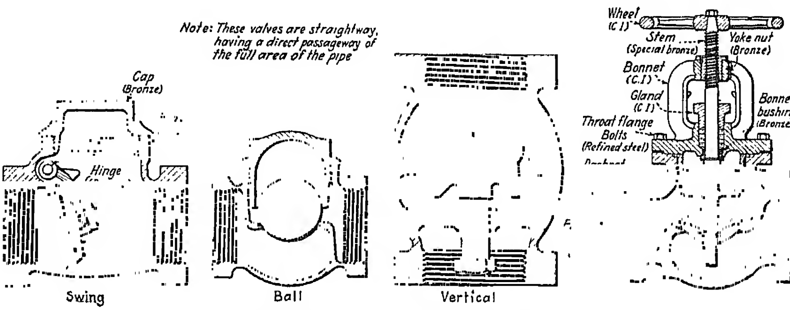


FIG. 54.—Types of check valves.

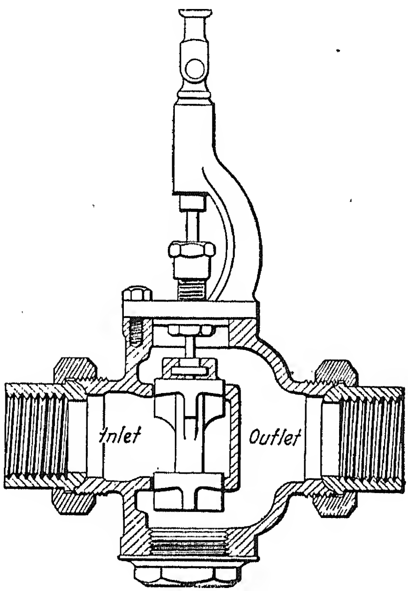


FIG. 55.—Section through a balanced valve. (*Mason Regulator Co.*)

installed on a house drain or house sewer to prevent the back flow of sewage into a building, or in many other situations. Four types of check valves are shown in Fig. 54. A back-water valve for a drainage pipe is illustrated in Fig. 163. In operation the

reversal of flow through the valve will force the closing disc into place thus cutting off the flow. In the installation of the check valve care should be taken that it is placed in the correct position and that a valve designed for a horizontal pipe is not placed on a vertical pipe or a vertical valve is not placed on a horizontal pipe, etc. Check valves are available for all positions.

70. Balanced Valves.—A balanced valve, as illustrated in Fig. 55, is used on pipe lines operating under such a high pressure that the opening of a gate valve or the closing of a globe valve against the pressure would be difficult. Balanced valves are also used on automatic-control devices such as filter rate controllers, engine governors, water-closet tanks, pressure regulators,

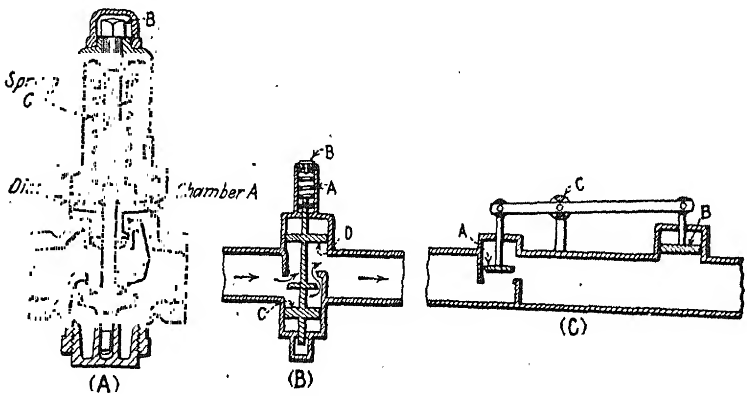


FIG. 56.—Sections through pressure-regulating valves.

etc. The valve has an inlet and an outlet end and it must always be placed with its inlet up stream. The pressure is then exerted equally against both discs and to move the discs it is necessary to overcome only the friction of the valve parts and to move the weight of the mechanism.

71. Pressure Regulators.—Pressure regulators may be used on water-supply lines where the supply pressure is greater than that desired in the plumbing system. They should be used in all cases where the pressure may exceed 80 to 90 lb. per square inch for long periods of time. Such a condition often arises in tall buildings and occasionally in hilly cities. Pressure regulators can be made to give any difference of pressure desired but the regulators available on the market are commonly limited to a minimum of 14 lb. per square inch for a pressure of 40 lb. per

square inch and a minimum of 40 lb. per square inch for a pressure of 200 lb. per square inch. Between these limits almost any desired pressure can be obtained.

The principle of operation of one type of pressure regulator is illustrated in Fig. 56A. The desired low pressure is fixed by turning the nut at *B* thus opening or closing the balanced valve which is supported on the flexible disc and the spring *C*. In operation, if the pressure below the valve tends to increase beyond the fixed amount the pressure in the chamber at *A* is increased forcing the disc up and partially closing the valve, thus reducing the pressure below the valve. If the pressure below the regulator becomes too low the pressure on the flexible disc is relieved and the spring *C* opens the balanced valve in the regulator.

Another type of regulator is shown in Fig. 56B. This is a less expensive type than the one described above but it is suitable only for the smaller sizes of pipe. It operates as follows: The high pressure from the inlet side operates against the disc *C* (the lower disc) to hold the valve open. The low pressure on the outlet side of the valve operates against the disc *D* (the upper disc) which is larger in area than disc *C*. The two pressures, with the aid of the spring *A*, just balance each other to hold the valve open in the correct position. Desired differences in pressure are obtained by adjusting the spring *A* by turning the screw *B*.

A third type of regulator is shown in Fig. 56C. It operates as follows: The high pressure operates against the small disc *A* to open it and the low pressure operates against the large disc *B* to close the valve at *A*. The location of the fulcrum *C* and the areas of discs *A* and *B* can be arranged to give the desired reduction in pressure.

Wherever pressure-reducing valves are installed on the service pipe of a building a by-pass should be provided for use when the valve is out of order. A pressure-relief valve should also be used to prevent the generation of excessive pressures in the plumbing system.

72. Pressure-relief or Safety Valves.—Pressure-relief or safety valves are used to prevent dangerously high pressures in plumbing systems, and for many other purposes. They are essential on hot-water supply systems where check valves are used to prevent the back flow of hot water and provision is not made for the expansion of the water or the possible generation of steam. The prin-

ciple of operation of the safety valve is illustrated in Fig. 57. The disc is held in place by an adjustable connection in the spring. When the pressure becomes too high, the disc is

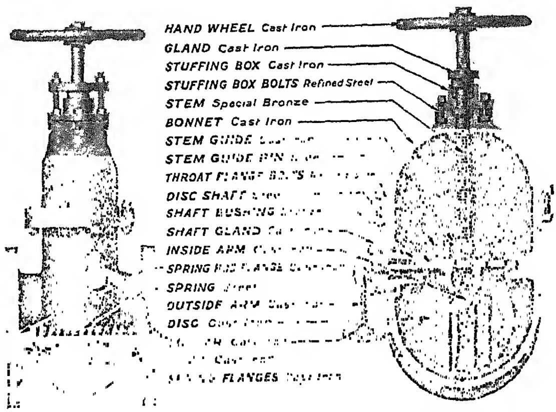


FIG. 57.—Combined swing gate and pressure-relief valve.

forced off its seat and the pressure in the tank or conduit is relieved. The valve should be designed with a free opening equal to or greater than the cross-sectional area of the pipe in which the pressure is to be relieved.

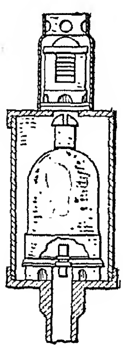


FIG. 58.—Air-relief valve.

73. Air-relief Valves.—An air-relief valve is shown in Fig. 58. These valves are used on water-supply systems in which air may become entrained to such an extent as to become a nuisance. If used, the water-supply pipes should be laid out on such a slope that air will rise through the pipes to the valve which is placed at the highest point on the system. The valve operates as follows: When the valve is filled with water the float presses the valve shut and no more water can escape. A bubble of air, rising through the air-relief pipe, will enter the valve chamber and displace some of the water therein. The float will drop thus opening the valve to release the air. Water will immediately follow into the valve chamber raising the float and closing the valve again.

74. Float-controlled Valves.—Float-controlled valves are in very common use in automatic apparatus used in plumbing installations. They are used principally on flush tanks, storage tanks,

and in all places where it is desired to maintain a constant level of water in a reservoir. A common type of float-controlled valve

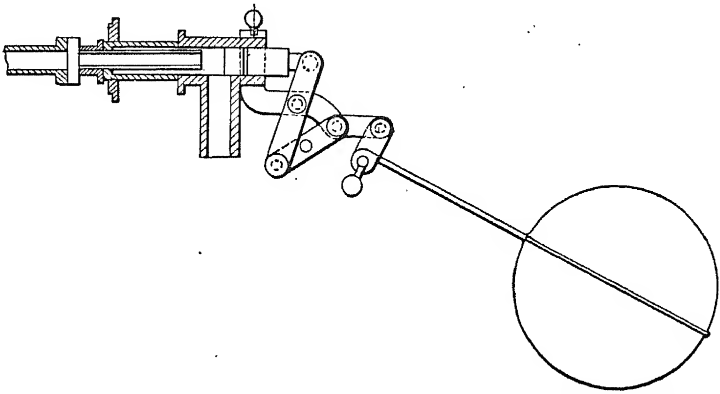


FIG. 59.—Detail of float-controlled valve used on water-closet flush tanks.

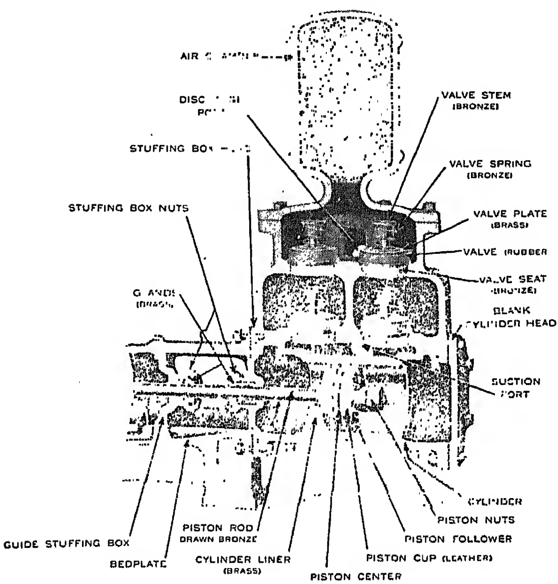


FIG. 60.—Section through water end of a pump showing valves, piston, packing glands, etc.

used in a water-closet flush tank is shown in Fig. 59. Many other types and modifications are used, as there is not a complete

plumbing installation in any building that does not contain a float-controlled valve.

75. Common Pump Valves.—The most common type of valve used in the suction and discharge chambers of pumps is shown in Fig. 60. It acts as a check valve allowing the water to flow in one direction only. Pressure beneath the valve lifts the leather disc off of the valve seat uncovering the port and permitting the passage of water. On the release of the pressure beneath the valve the reverse tendency of the water, aided by the valve spring, forces the disc back on to the seat. A foot valve used for the suction line of a pump is shown in Fig. 61. This consists of a large number of small "common" valves placed in the bottom of the foot piece. Another type of foot valve consists of a single, hinged flap in the place of the many small valves.

76. Butterfly Valves.—A butterfly valve is illustrated in Fig. 62. It consists of a disc, somewhat like the damper in a stovepipe, which is shaped to fit the inside of the pipe as far as the disc will turn. When the valve is closed the disc fits against a ground faced seat, but unfortunately it is difficult to make and to maintain a tight fit for such a valve. Butterfly valves are used in automatic apparatus, in throttle valves, and as quick-closing valves.

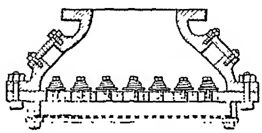


Fig. 61.—Foot valve.

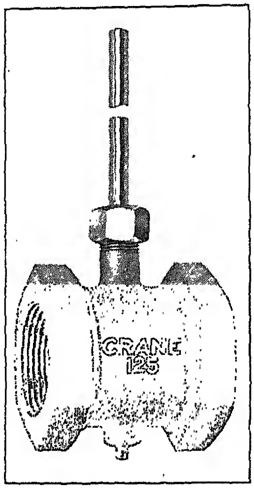


Fig. 62.—Butterfly valve. (*Courtesy Crane Co.*)

77. Needle Valves.—Needle valves, such as are illustrated in Fig. 63 are used in the handling of gases or where it is desired to obtain a very fine adjustment of the opening of the port.

78. Four-way and Three-way Valves.—Four way and three-way valves are used in special mechanisms where it is desired to divert the flow from one incoming channel to any one of two or three possible outlet channels, or where it is desired to connect an

incoming and an outgoing channel immediately after a different pair of incoming and outgoing channels have been disconnected. One type of four-way valve is shown in Fig. 64.

79. Fuller Faucets.—The Fuller faucet, illustrated in Fig. 65, is not so commonly used now as a few years ago. The parts for the shutting off of the water supply consist of a soft rubber ball

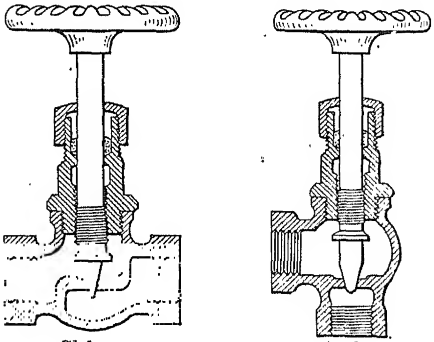

Globe
Angle

FIG. 63.—Straight and angle needle valves.

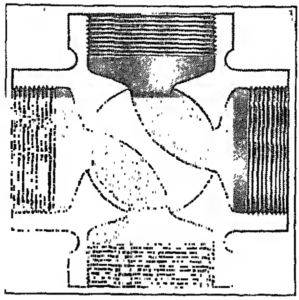


FIG. 64.—Section through a four-way valve.

marked *A*, which fits into a cup-shaped seat and is forced on to the seat by the turning of the faucet handle. The ball makes a tight joint but it does not wear well, is affected by heat and by corrosive liquids, and is not easily replaced. It has the advantage that the faucet can be opened wide by a one-fourth turn of

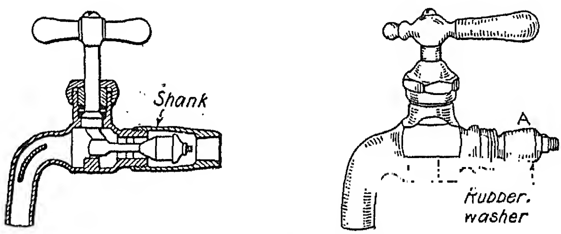


FIG. 65.—Fuller faucet.

the valve handle, but the quick closing of the valve may result in serious water hammer in the plumbing system.

80. Compression Faucets.—A compression faucet is an adaptation of the globe valve. It is commonly used on bathtub, lavatory, and some other plumbing fixtures. Its construction is illustrated in Fig. 66. The faucets are equipped with a soft gasket or packing, shown in the figure. This requires occa-

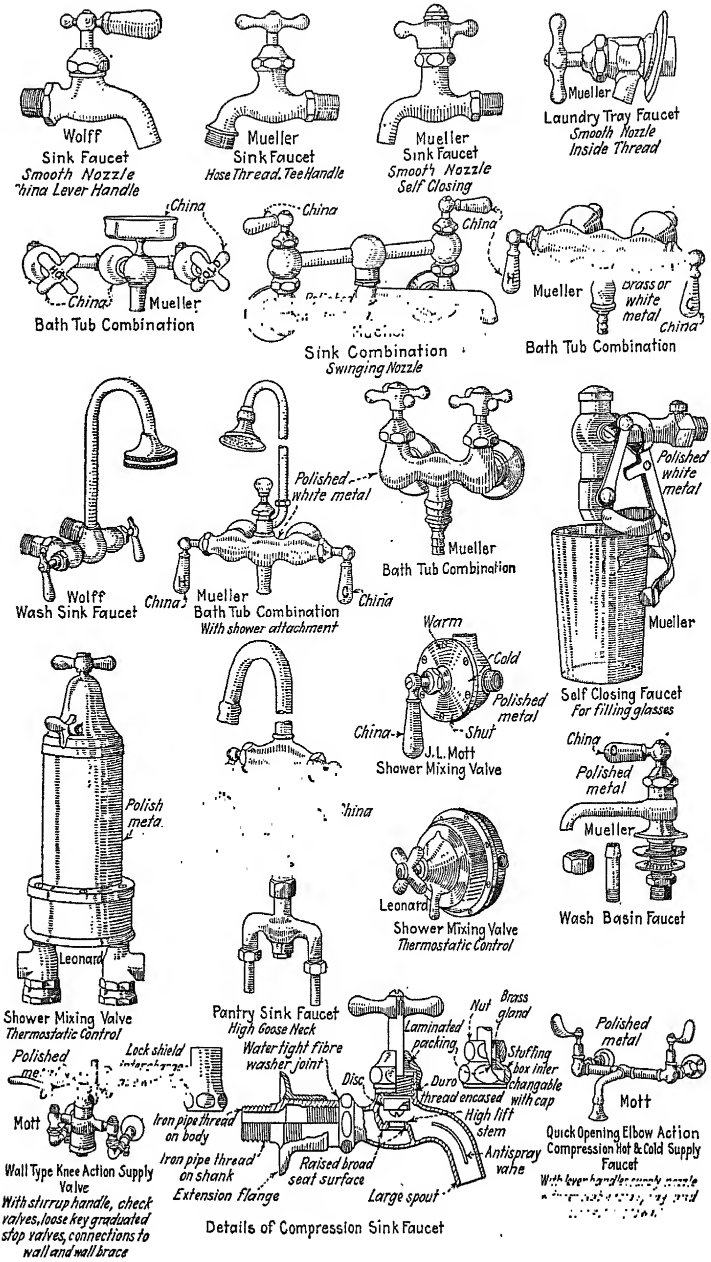


Fig. 66.—Types of faucets and shower-bath mixing valves.

sional renewal and may give much trouble if exposed to hot water under a high pressure. There are two general types of these faucets and many modifications. In one type the barrel is threaded to receive a correspondingly threaded plunger which carries the washer to the seat, and the second type in which the threaded stem actuates a squared plug which moves up and down inside a barrel squared to receive it. Compression faucets are open to many of the same objections as the globe valve, particularly with regard to the tortuous passages, small water way, and relatively high loss of head. The faucets require a number of turns to open or to close them. The effort is sometimes bothersome to the user but the slow motion is a certain preventive of excessive water hammer.

81. Self-closing Faucets.—Self-closing faucets are used in cheap hotels, lodging houses, public lavatories, and institutions. Their principal purpose is to prevent water waste. A type commonly used is illustrated in Fig. 66. It is of the compression type of faucet but the valve disk is held on the seat by a strong spring which is compressed by a lever action or by means of a screw thread with a steep pitch. Although helpful for their purpose, which is to prevent water waste, they are not infallible as they are more or less easily tied or blocked open. As they usually close very quickly when operating properly they nearly always produce water hammer under moderate or high pressures.

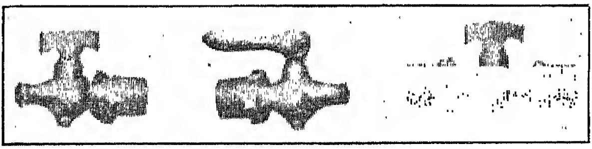


FIG. 67.—Pet cocks, air cocks, or faucets.

82. Pet Cocks.—The pet cock, air cock, or faucet, shown in Fig. 67, is used as a drain for pipe lines, valves or appurtenances; to test containers for the presence of liquid or gas under pressure behind the pet cock; for connecting pressure gages; and for other useful purposes. They are seldom threaded for pipe larger than $\frac{3}{8}$ in.

83. Stop-and-waste Valves.—The stop-and-waste valve, shown in Fig. 68, is used on water-supply lines, and so operates that when the water supply is shut off the water remaining in the pipe, on the non-pressure side of the valve, will drain out through

the waste which is opened when the pressure side of the valve is shut off. A stop-and-waste valve should be installed on the house end of all service pipes where the service pipe comes through the basement wall of the building, or if a meter is installed it should be placed close to the meter and on the street side thereof. This type of valve is essential to the protection of the water pipes against freezing when the heat and water are turned off in a building in cold weather.

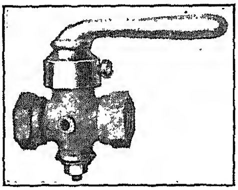


FIG. 68.—Stop and waste valve.

84. Water-closet Flush Valves.—Water closets may be flushed by admitting water directly to the bowl of the closet from the water-supply pipes of the plumbing system. In order to avoid the use of an excessive amount of water a valve should be used which will remain open just long enough to deliver the required amount of water and will then close automatically. It should be so designed that it cannot be held open for full flush.

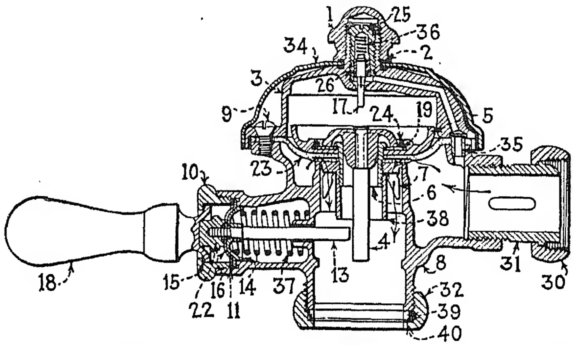
Many types of water-closet flush valves are manufactured, each showing some difference from the others. A section through a type of flush valve manufactured by the Imperial Brass Company is shown in Fig. 69. It operates as follows:

The flush valve has two main compartments or chambers, the upper one being bounded by the inside cover No. 3 and the rubber diaphragm No. 23, while the lower chamber is separated by this rubber diaphragm and is under direct water pressure at all times. The flush valve becomes active by merely a slight movement of the oscillating lever handle No. 18 which actuates the operating stem No. 13, thereby raising relief-valve stem No. 4. The raising of this stem opens hole No. 6 permitting water to escape from the upper to the lower chamber, and thence into the closet bowl or urinal. The lowering of the pressure in the upper chamber results in the lifting of diaphragm No. 23 resulting in the opening of the main outlet from the supply pipe to the fixture, the water following the course marked by the arrow.

In the meantime the pressure in the upper chamber is being restored by the water flowing through the by-pass channel No. 35, thus forcing diaphragm No. 23 downwards and cutting off the flow of the water to the fixture.

The amount of flush is regulated by raising or lowering stem No. 17 which controls the amount of the opening of diaphragm No. 23.

The desirable conditions for the installation of water-closet flush valves are discussed in Secs. 254 and 256 on pages 298 and 299.



1. Cap nut to conceal regulating screw
2. Fibre washers (two required)
3. Inside cover
4. Relief-valve stem complete (Nos. 28 and 29)
5. Weight for diaphragm
6. Guide for relief-valve stem
7. Refill disc lock nut
8. Valve body
9. Screws for inside cover (five required)
10. Bonnet nut for handle
11. Brass friction washer for bonnet nut
13. Operating stem
14. Cup washer for operating stem
15. Bearing washer
16. Flexible rubber washer for operating stem.
17. Plunger for regulating screw
18. Handle, complete (porcelain or metal)
19. Rubber seat washer for relief valve
22. Cap nut for operating stem
23. Rubber diaphragm
24. Wire retaining ring
25. Regulating screw (body only)
26. Hexagon sleeve for regulating screw
30. Coupling nut for shut off
31. Coupling nipple for shut off
32. Coupling nut for flush connection
34. Shield or outside cover
35. By-pass tube
36. Spring for regulating screw
37. Spring for operating stem
38. Baffle tube
39. Rubber washer for flush connection
40. Brass friction washer for flush connection
41. Regulating screw, complete (Nos. 17, 25, 26, 36)

FIG. 69.—Section through a flush valve. (*Imperial Brass Co.*)

Reference

1. COSGROVE, J. J., "Faucets, Cock, and Valves," *Plumbers Trade Jour.*, Vol. 75, p. 758, 1923.

CHAPTER VI

HOT-WATER AND CHILLED-WATER SUPPLIES

85. Heating Water.—Running hot water is obtained by heat applied in water backs in kitchen ranges, as illustrated in Figs 70 and 190; by special water heaters containing a water coil, as illustrated in Fig. 71; by a water coil placed in the furnace; by a gas or gasoline heater, one type of which is illustrated in Fig. 72; and by other less common methods. Pipe coils in furnaces are safer than tanks against explosion but they clog more easily.

The heaters available on the market can be divided into two classes: those which are heated directly by fuel, and those which are heated by steam. The former are used mainly for household installations and where it is desirable to

FIG. 70.—A water-back for a kitchen range. (*Reading Foundry and Supply Co.*)

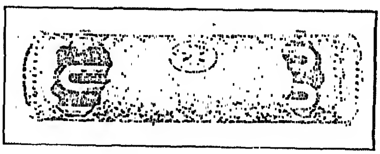


FIG. 71.—Water heater containing a coil. (*L. O. Koven Brothers.*)

get hot water quickly, and for automatically controlled apparatus. For quick heating the water must be divided up into many small heating units subject to a high temperature. Copper tube coils are commonly used with gas, and cast-iron boxes, called water backs, and iron pipe coils are used with coal. The capacities of heating apparatus for dwellings and apartments are given in Table 44. In any hot-water supply system the water should be heated to a temperature between 150 and 180° F.

TABLE 44.—CAPACITIES OF HOT-WATER HEATING APPARATUS RECOMMENDED FOR DWELLINGS AND APARTMENT HOUSES[1]

Number of families	Capacity, gallons per hour	Coal heater				Gas heater	Steam heater				
		Grate area, square feet	Heating surface, square feet	Flue diameter, inches and height, feet	Coal used in 8-hr. firing period, pounds	Cubic feet of gas per hour	Pounds of steam per hour	Area of steam pipe required, square feet	B.t.u. added to water per hour	Required storage-tank capacity, gallons	Circulating pipe size between heater and storage tank, inches
1	10	0.25	5.0	8 in. by 10 ft.	10	21	10.5	0.3	10,030	30	1
2	20	0.33	6.6	8 in. by 20 ft.	21	42	21.0	0.9	20,060	60	1¼
3	30	0.47	9.4	8 in. by 20 ft.	30	63	31.3	1.4	30,080	90	1½
4	40	0.60	12	8 in. by 20 ft.	38	84	41.8	1.9	40,100	120	2
6	60	0.90	18	10 in. by 20 ft.	57	125	62.7	2.8	60,160	180	2½
8	80	1.2	24	10 in. by 30 ft.	76	167	83.6	3.7	80,210	240	2½
10	100	1.5	30	10 in. by 40 ft.	96	209	104	4.7	100,260	300	3
12	120	1.8	36	10 in. by 50 ft.	115	251	125	5.6	120,320	360	3
15	150	2.2	45	12 in. by 20 ft.	143	313	157	7.0	150,390	450	4
18	180	2.7	53	12 in. by 25 ft.	170	376	188	8.4	180,470	540	4
20	200	3.0	59	12 in. by 30 ft.	190	418	209	9.3	200,500	600	4
25	250	3.8	75	12 in. by 50 ft.	240	522	261	11.7	250,700	750	4
30	300	4.5	90	12 in. by 60 ft.	286	626	313	14.0	300,800	900	5
35	350	5.3	105	14 in. by 30 ft.	335	731	366	16.3	350,900	1,050	6
40	400	6.0	119	14 in. by 40 ft.	380	835	418	18.7	401,000	1,200	6
50	500	7.4	148	16 in. by 30 ft.	475	1,044	522	23.3	501,300	1,500	6
60	600	9.0	180	16 in. by 40 ft.	575	1,253	627	28.0	601,800	1,800	6
75	750	11.2	224	18 in. by 40 ft.	715	1,567	783	35.0	752,000	2,250	8
90	900	13.5	268	18 in. by 50 ft.	860	1,800	940	42.0	902,400	2,700	8

[1] CLEVERDON, W. S. L., *Plumbers' Trade Jour.*, Vol. 73, p. 164, 1922.

86. Coal-fired Heaters.—The size of a coal-burning water heater is measured by the area of the grate. The capacity of the heater is fixed by the area of the grate and the rate at which it will burn coal. Ordinarily a heater can be expected to burn about 3 to 6 lb. of coal per square foot of grate surface per hour, dependent on the construction of the heater, the fuel, and the draft. From 6,000 to 8,000 B.t.u. will be transmitted to the water per pound of coal. Since one British thermal unit (B.t.u.) is the amount of heat necessary to raise the temperature of 1 lb. of water 1° F., the approximate capacity of the heater can be calculated from the above information. Such calculations can be expected to be within 50 to 150 per cent of the correct amount and heaters should be designed for overcapacity as they frequently fail to give the expected results.

Example.—If water is delivered to a heater at a temperature of 50° F. how many gallons of water per hour at a temperature of 150° F. will be delivered by the heater? The heater has a grate area of 2 sq. ft. and the areas and materials of the heating surfaces are assumed to be adequate for the absorption of the heat from the fuel. The 2 sq. ft. of grate surface will permit the combustion of 8 lb. of coal per hour.

The B.t.u. delivered to the water will be assumed to be 6,000 × 8 = 48,000 B.t.u. per hour.

48,000 B.t.u. will raise 480 lb. of water 100° F.

480 lb. of water is approximately 58 gal.

Therefore, the heater will have a capacity of 58 gal. of water per hour from 50 to 150° F.

The design of the combustion chamber of the heater should be such as to provide a capacity of at least ½ to 1 cu. ft. for each square foot of grate area, dependent on the kind of fuel used and the frequency of firing. Anthracite coal requires less combustion space than bituminous coal. An adequately designed heater will require firing three to four times a day. About one-half of the volume of the combustion chamber should be occupied by the fuel. For small heaters the area of the flue is taken at about 12 to 15 per cent of the grate area. For large heaters, it may be economical to apply the principles of chimney design to the design of the flue.

87. Gas Heaters.—Gas water heaters, such as are shown in Fig. 72, include manually operated, automatic, and instantaneous heaters. Some heaters are equipped with a thermostat which controls the gas supply so that when the water falls below a certain temperature the gas is automatically turned on. In some types the storage tank is well insulated to economize in the use of gas. Instantaneous heaters are arranged so that the opening of a faucet on the hot-water line will increase the flow of gas, which is lighted by a continuously burning pilot light, so as to heat the water to about 110 to 130° F. in the pipe coils as it flows through the hot gases. The possibility of the dying out of the pilot light offers a source of danger to the use of automatic gas appliances depending on a pilot light. Gas heaters are dangerous at their best, and they should be designed to prevent the accumulation, in a confined space within the heater, of a large volume of an explosive mixture. The provision of a ventilating flue is desirable to carry off the products of combustion and as a safety factor to carry off unburned gas. The gas and water valves should be interlocked so that the gas cannot be

turned on unless the water is also turned on and is in the heater coils. The burning of gas produces water of condensation which is immediately evaporated in continuous heaters. In instantaneous heaters, however, some of the water is precipitated and drip pans with proper wastes must be provided for its disposal.

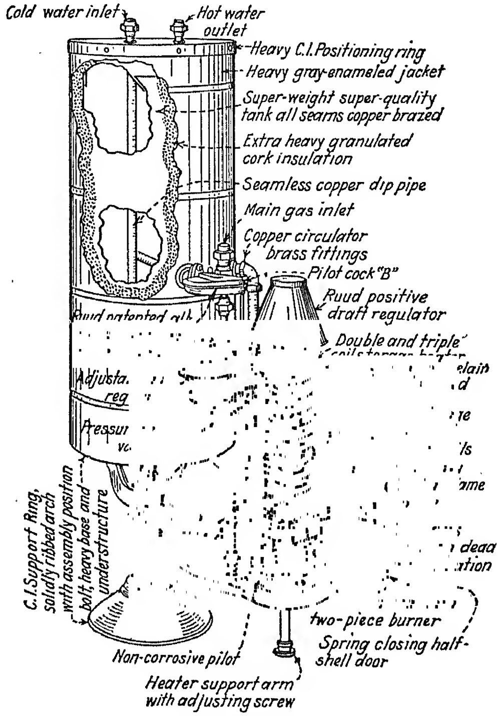


FIG. 72.—Ruud gas water heater.

The amount of gas required for heating water can be computed from the expression,

$$G = \frac{8.3Q(T_1 - T_2)}{H}E$$

in which G = the amount of gas required, in cubic feet.

Q = the amount of water to be heated, in gallons.

T_1 = the final water temperature in degrees Fahrenheit.

T_2 = the original water temperature in degrees Fahrenheit.

H = the B.t.u. delivered by the combustion of 1 cu. ft. of gas.

E = the efficiency of the heating coils in absorbing heat.

There are about 500 to 600 B.t.u. in 1 cu. ft. of illuminating gas and 1,000 B.t.u. in a cubic foot of natural gas. It is assumed, in the above expression, that the pipe coils and the combustion chamber are properly designed to permit the absorption of heat by the water. With good design the efficiency of the heater should be between 80 and 95 per cent.

88. Distribution of Hot Water.—Two methods of arranging piping for the distribution of hot water are shown in Fig. 73. It is to be noted that under the conditions illustrated in Fig.

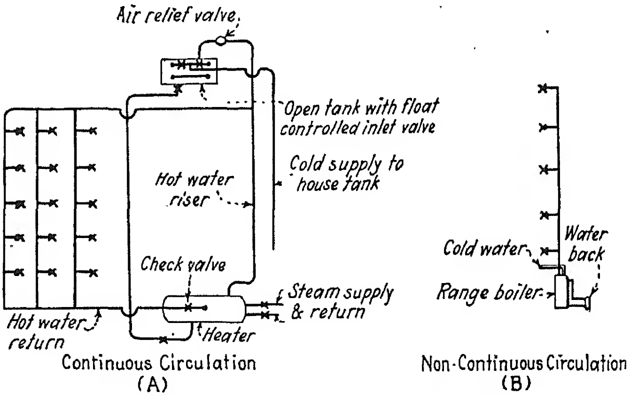


FIG. 73.—Diagrams of hot-water supply pipes.

73B the hot water lies motionless in the pipe until the faucet is opened. Such an installation is often the simplest but it results in a waste of water because the householder will allow the water to run until it gets hot. A continuously circulating system is shown in Fig. 73A. In this system the hot water will flow from the faucet as soon as it is opened. An objection to this system is that from 10 to 25 per cent of the fuel may be used in circulating the water but the amount of water and time saved and the greater convenience will often compensate for the additional expense.

89. Insulation of Hot-water Pipes.—Loss of heat can be reduced by covering the pipes and the storage tank with a material which is a poor conductor of heat. The pipe should be covered to a thickness of about 1½ in. Beyond this

thickness the insulating effect is not materially increased. The loss of heat from the bare pipes may be reduced 75 to 80 per cent by covering them, but the actual loss of heat in a residence is so small that hot water pipes in residences are not always covered.

90. Circulation of Hot Water.—In the installation of a circulating hot-water system the riser pipe should have two to three times the cross-sectional area of the return pipe and no riser main should be less than ¾ in. in diameter. This provision is to assure the proper circulation of the water. Otherwise cold or tepid water may be present in the return pipe and be drawn from it due to reversed circulation. To assure good circulation the return pipe should be brought from the highest point in the line to the bottom of the heater and in sloping runs it should always be pitched toward the heater.

When circulation is maintained by a pump the capacity of the pump can be determined by dividing the total estimated heat loss, expressed in B.t.u., by 10, on the assumption that the return water is 10 deg. cooler than in the heater. The quotient will give the pounds of water to be circulated. The head pumped against should be assumed as 5 lb. per square inch more than the cold-water pressure and to this should be added friction loss in the pipes. When no circulating pump is used the velocity of flow of the water depends on the difference in temperature of the water in the riser and in the return pipes. The weight of water at various temperatures is shown in Table 45. The difference in weight of the two columns of water, expressed in pounds with each column assumed to be one square foot in cross-sectional area, divided by 62.5 will give the head or pressure causing motion, expressed in feet of water. The effective head is equal to this amount less the friction head caused by flow in the pipe. The velocity of flow will equal $\sqrt{2gh}$ in which h is the effective head, in feet, and g is the acceleration due to gravity which is ordinarily taken as 32 ft. per second per second. The computation is complicated because a trial velocity must be assumed and the head checked until the correct velocity has been found.

In supplying hot water to a fixture the hot-water faucet is usually placed on the left of the person using the fixture.

91. Connecting Up Heaters and Storage Tanks.—The Committee on Simplified Practice of the U. S. Department of Commerce has proposed a standard method for connecting up

TABLE 45.—TEMPERATURE, VOLUME, AND BOILING POINT OF WATER

Temperature degrees Fahrenheit	Relative volume	Relative density	Weight per cubic foot, pounds	Temperature, degrees Fahrenheit	Relative volume	Relative density	Weight, per cubic foot, pounds	Approximate gage pressure, pounds square inch	Absolute pressure	Boiling point, degrees Fahrenheit	Approximate gage pressure, pounds square inch	Absolute pressure	Boiling point, degrees Fahrenheit
32	1.00000	1.00000	62.418	140	1.01690	0.98339	61.381	−14	1	102.018	17	32	254.002
35	0.99993	1.00007	62.422	145	1.01839	0.98194	61.291	−13	2	126.302	19	34	257.523
39.1	0.99989	1.00011	62.425	150	1.01889	0.98050	61.201	−12	3	141.654	21	36	260.883
40	0.99989	1.00011	62.425	155	1.02164	0.97882	61.096	−11	4	153.122	23	38	264.093
45	0.99993	1.00007	62.422	160	1.02340	0.97714	60.991	−10	5	162.370	25	40	267.168
46	1.0000	1.00000	62.418	165	1.02589	0.97477	60.843	− 9	6	170.173	27	42	270.122
50	1.00015	0.99985	62.409	170	1.02690	0.97380	60.783	− 8	7	176.945	29	44	272.965
52.3	1.00029	0.99971	62.400	175	1.02906	0.97193	60.665	− 7	8	182.952	31	46	275.704
55	1.00038	0.99961	62.394	180	1.03100	0.97006	60.548	− 6	9	188.357	33	48	278.348
60	1.00074	0.99926	62.372	185	1.03300	0.96828	60.430	− 5	10	193.284	35	50	280.904
62	1.00101	0.99899	62.355	190	1.03500	0.96632	60.314	− 4	11	197.814	37	52	283.381
65	1.00119	0.99881	62.344	195	1.03700	0.96440	60.198	− 3	12	202.012	39	54	285.781
70	1.00160	0.99832	62.313	200	1.03889	0.96256	60.081	− 2	13	205.929	41	56	288.111
75	1.00239	0.99771	62.275	205	1.04140	0.9602	59.93	− 1	14	205.604	43	58	290.374
80	1.00299	0.99702	62.240	210	1.0434	0.9584	59.82	0	[5]	212.00	45	60	292.575
85	1.00379	0.99622	62.182	212	1.0444	0.9575	59.76	0	15	213.067	47	62	294.717
90	1.00454	0.99543	62.133	230	1.0529	0.9499	59.26	1	16	216.347	49	64	296.805
95	1.00554	0.99449	62.074	250	1.0628	0.9411	58.75	2	17	219.452	51	66	298.842
100	1.00639	0.99365	62. 22	270	1.0727	0.9323	58.18	3	18	222.424	53	68	300.831
105	1.00739	0.99260	61.960	290	1.0838	0.9227	57.59	4	19	225.255	55	70	302.774
110	1.00889	0.99119	61.868	298[1]	1.0899	0.9175	57.27	5	20	227.964	57	72	304.669
115	1.00989	0.99021	61.807	338[2]	1.1118	0.8994	56.14	7	22	233.069	59	74	306.526
120	1.01139	0.98874	61.715	366[3]	1.1301	0.8850	55.29	9	24	237.803	61	76	308.344
125	1.01239	0.98808	61.654	390[4]	1.1444	0.8738	54.54	11	26	242.225	63	78	310.123
130	1.01390	0.98630	61.563	......	......	......	......	13	28	246.376	65	80	311.866
135	1.01539	0.98484	61.472	......	......	......	......	15	30	250.293	67	82	313.576
											69	84	315.250
											71	86	316.893
											73	88	318.510
											75	90	320.094
											77	92	321.653
											79	94	323.183
											81	96	324.688
											83	98	326.160
											85	100	327.625
											90	105	331.169
											95	110	334.582
											100	115	337.874
											105	120	341.058

[1] Steam at 50 lb. per square inch.
[2] Steam at 100 lb. per square inch.
[3] Steam at 150 lb. per square inch.
[4] Steam at 205 lb. per square inch.
[5] Exact = 14.69 lb. per square inch absolute

hot-water storage tanks, which is illustrated in Fig. 190. Other methods of installing the storage tank are shown in the same figure. The standard details for storage-tank sizes, dimensions, etc. are given in Appendix I, Sec. 16.[5,6] Since water is a poor conductor of heat, it cannot be heated successfully by heating the water at the top of a storage tank. The heat must be applied at the bottom and circulation currents depended on to convey the heat throughout the tank.

Where two heaters are to be connected to the same storage tank, as is sometimes desirable in a residence equipped with a kitchen range and a laundry stove, or where there is a heater in the furnace as well as in the kitchen range, or for any other reason where there are two heaters, the two heaters should be connected independently to the storage tank and with as nearly as possible, the same amount of friction in the pipes to each heater. Where heaters are connected to each other in parallel, the flow through one is likely to interfere with the flow through the other, or where they are connected in series the arrangement is inefficient because when both fires are going the water coming to one heater is warm and it does not absorb so much heat, and when only one fire is going the water is chilled in passing through the cold heater unless the cold heater is on the opposite side from the storage tank.

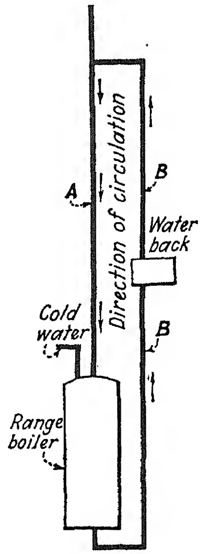


FIG. 74.—Range boiler connection.

It is undesirable to place a storage tank below a heater because of the inefficiency of the resulting circulation. It is difficult to force the hot water down into the tank. Circulation can be obtained, however, by connecting the hot-water pipe from the heater to the riser pipe from the tank at a height as far or farther above the heater than the heater is above the bottom of the storage tank. This connection is illustrated in Fig. 74. Pipe A should be smaller than pipe B.

A high-pressure steam boiler should not be connected directly into the water-supply pipes of the plumbing system. It is also desirable to provide a tank of at least 6-hr. supply so that in the event of the shut-down of the water supply there will be sufficient water to avoid danger of explosion in the boiler.

92. Storage Tanks.—Storage tanks for hot water are necessary except in some cases where "instantaneous" heaters are used. The capacity of the hot-water storage tank should be fixed by the number of persons using it and the purpose to which it is to be put. For ordinary domestic supplies there should be about 30

Table 46.—Recommended[1] Capacities of Hot-water Heating Equipment to Supply Fixtures in Various Types of Buildings
(Gallons per hour per fixture)

Fixture	Apartment house	Club	Gymnasium	Hospital	Hotel	Industrial plant	Laundry	Office building	Public bath	Private residence	School	Y. M. C. A.
Private lavatory	3	3	3	3	3	3	3	3	3	3	3	3
Public lavatory	5	8	10	8	10	15	10	8	15	...	18	10
Bathtub	15	15	30	15	15	30	...	...	45	15	...	30
Dish washer	15	30	...	30	30	30	...	...	...	15	15	
Foot basin	3	3	12	3	3	12	...	...	...	3	3	12
Kitchen sink	10	20	...	20	20	20	...	...	...	10	10	20
Laundry stationary tubs	25	35	...	35	35	...	42	...	...	25	...	35
Laundry revolving tubs	75	75	...	100	150	...	75 to 100	...	100	75	...	100
Pantry sink	10	20	...	20	20	...	...	...	...	10	20	20
Shower	100	200	300	100	100	300	...	...	300	100	300	200
Slop sink	20	20	...	20	30	20	10	15	15	15	20	20
Dish washer	200 gallons per hour at 180° per 500 people											
Dish washer[2]	300 gallons per hour at 180° per 500 people											
Total water for all fixtures likely to be drawn at one time	35	60	80	75	60	90	100	20	100	50	25	
Per cent[3]	20	50	80	60	50	90	100	15	100	50	25	
Storage capacity in per cent of maximum heating capacity	35	40	40	45	45	50	50	40	50	30	40	

Apartments. One kitchen and one bath

Number of families	up to 25	25 to 50	50 to 75	70 to 100	over 100
Gallons per hour per family	35	30	25	20	15

Swimming pools

Fill in 24 hr. Refilter every 24 hr. 50,000-gal. pool good for 100 persons.

[1] Buenger, Albert, *Jour. Am. Soc. Heat. Vent. Eng.*, Vol. 26, p. 701, 1920.
[2] Computed at final temperature of 150° F.
[3] The figures in this line are from discussion by Perry West in *Jour. Am. Soc. Heat. Vent Eng.*, Vol. 27, p. 253, 1921

gal. per family of four or five persons, provided the heating plant is sufficient to warm the entire amount of water used in an hour 30° F. for a dwelling and 45° F. for an apartment building. As the number of persons drawing water from the tank increases the amount of storage allowed per person can be diminished. Table 46 shows, approximately, the proper allowance for hot-water storage in residence and apartment buildings. The dimensions of storage tanks are shown in Tables 130, 132, and 133.

West[7] states:

> I have found it advantageous to divide apartment houses into three classes, *A*, *B*, and *C*, corresponding respectively to high-class, ordinary, and tenement-class apartments. The ratio of the demand for these three classes runs about in the proportion of 100, 80, and 60.

Many local factors may seriously affect the demand and should be allowed for in an estimate. For example, if water is delivered at 125° instead of 180°, 50 per cent more water will be required. In office buildings using ordinary compression faucets, twice as much water will be used as would have been used with self-closing faucets.

It is to be noted that hot water, unlike cold water, is always stored in pressure tanks. The storage of hot water in open tanks would entail the loss of too much heat and water by evaporation. The piping connections to open tanks would be more complicated, would require longer runs of pipe, and would make more difficult the assurance of the circulation of hot water from the tank into the heater.

Storage tanks should be equipped with a blow-off valve at the bottom so as to permit the blowing-off of the sediment which may accumulate there, and also to permit the drawing-off of water for any other purpose. The discharge from the blow-off valve should lead into a sink or other fixture. It should not be connected directly to the house drainage pipes below a trap. If a check valve is used on the water-supply line some method for pressure relief, such as a safety valve, must be used.

93. Tank and Pipe Material.—Hot-water storage tanks used for domestic supplies are made of either galvanized iron or copper. The former is usually stronger, particularly against collapse resulting from the creation of a vacuum in the tank, but the latter is more durable, is usually free from corrosion, and will

not cause the staining of clothing or plumbing fixtures as iron storage tanks sometimes will.

Brass or copper pipes are best suited to convey hot water because of their resistance to corrosion, which is more active in hot than in cold water. Steel or iron pipes are satisfactory though they may be badly corroded unless the water is inactive. Lead should never be used for hot water as it dissolves too rapidly and it softens so much at the higher temperature, particularly at the joints, that it is not safe against internal pressure.

The installation, near the heater, of a chamber containing silicate of soda through which the hot water flows is an aid to preventing the corrosive action of hot water on iron. The dissolved silicate of soda forms a protective coating over the corroded places in the iron.[8]

94. Insulation of Hot-water Storage Tanks.—Hot-water storage tanks are sometimes covered with an asbestos jacket to prevent the loss of heat from them. The saving effected is great as has been demonstrated by tests made at the University of Pittsburgh.[9] The final conclusions of these tests are:

1. A saving of about 30 per cent of the total amount of gas usually burned can be effected by insulating a 30-gal. hot water boiler with tank jacket.

2. A considerable saving in gas can be effected by insulating all exposed hot-water piping, etc.

3. The tank jacket will hold the heat in the water for a considerable time after the fire has been shut off.

Hot-water storage tanks in residences are seldom covered except when the storage tank is placed in the basement where the unsightly covering is not so prominent as it would be in the kitchen. Storage tanks used with automatic heaters are usually covered to conserve the heat.

95. Size of Water-back and Pipe Coil.—The area of the surface of water-back or heating coil to be exposed to the fire depends on the capacity of the water storage tank, the temperature of the fire, and the material of the coil or water-back. There is more danger of getting the area too small than too large, although where water coils are used in furnaces that are designed for heating the building more water may be heated than can be used and steam may be formed in the pipes. Water-backs are usually made of cast iron and have a heating capacity of 25 to 35 gal. per hour per square foot of surface exposed to the fire. They present

about 100 sq. in. of surface to the fire and will heat about 17 to 25 gal. per hour to 150° F. Cast-iron water-backs are generally unsafe at pressures higher than 75 lb. per square inch. The approximate sizes of heating coils to be used are given in Table 47.

TABLE 47.—CONSTANTS FOR COMPUTATION OF STEAM COIL SIZES IN WATER HEATERS

Condition of steam	Kind of coil	Constant[1]	Condition of steam, pounds per square inch	Kind of coil	Constant[1]
Exhaust	iron pipe	10	25	copper pipe	30
Exhaust	copper pipe	15	50	iron pipe	25
5 lb. per square inch	iron pipe	15	50	copper pipe	40
5 lb. per square inch	copper pipe	22	75	iron pipe	33
25 lb. per square inch	iron pipe	20	75	copper pipe	50

[1] The constant is the figure by which the number of gallons of water heated per hour is to be divided to give the square feet of coil.

The size of the heating coil can be computed from the following expression:

$$A = 8.3Q \div f \text{ (reference 10)}$$

in which A = the area, in square feet, of inside surface of the pipe coil exposed to the fire.

Q = the quantity of water, in gallons per hour, flowing through the coil.

f = a coefficient of heat exchange. For iron $f = 145$ to 200, for brass or copper $f = 220$ to 300.

The relative effectiveness of brass and iron for heating coils, as allowed by this formula, should be noted.

If the water-back or heating coil is made too large for the capacity of the storage tank the water will be overheated. It will turn to steam when a faucet is opened and a crackling noise will probably be heard in the pipes. The proportioning of the storage tank and the heater requires a knowledge of the conditions of operation of the system, but fortunately a wide range of difference in capacity is possible with successful results. A water back with a 100-sq. in. area of heating surface will supply a storage tank of 30- to 35-gal. capacity for ordinary domestic service. The capacity of the heater should be sufficient to care for the average demand during the period of activity in the building and the storage tank should aid during periods of peak demand.

In using a heating coil in a furnace the coil should be buried in the hot coils of the fire. Such a coil usually consists of two lengths of straight pipe and a return bend. The coil should not be placed in the gas chamber above the fire as it will not heat so well in this location.

96. Steam Heaters.—The sizes of coils in heaters using steam coils immersed in water or coils of water surrounded by steam is determined by the amount of water to be heated, the temperature of the steam, and the material of which the coils are made. The area of the inside surface of a heating coil can be found from the expression:

$$A = \frac{Q \times (T_1 - T_2)}{f\left(T_s \frac{T_1 - T_2}{2}\right)} 8.3 \qquad (1)$$

in which

A = area, in square feet of the inside surface of the heating coil.

f = the coefficient of heat transmission. For iron $f = 200$, for brass and copper $f = 300$. It is expressed as the number of B.t.u. transmitted per hour per square foot of surface.

T_1 = the temperature of the hot water, degrees Fahrenheit.

T_2 = the temperature of the cold water, degrees Fahrenheit

T_s = the temperature the steam in degrees Fahrenheit.

Q = the amount of water to be heated per hour, expressed in gallons.

The temperature of steam at various significant pressures is shown in Table 45. The steam coil should be so arranged in the tank that water of condensation will drain out and heated water will rise to, and leave at, the highest point in the coil. The number of pounds of steam used can be computed from the expression,

$$P = \frac{8.3Q(T_1 - T_2)}{C_1 - C_2} \qquad (2)$$

in which

P = the steam delivered to the heater in pounds per hour.

C_1 = the original heat content of the steam in B.t.u. per pound.

C_2 = the heat content of the steam or the condensed steam in leaving the heater, expressed in B.t.u.

T_1 and T_2 are as in equation (1).

The heat content of steam at various temperatures will be found in tables showing the properties of saturated steam. Ordinarily it is most economical to condense all of the steam delivered to the heater and reduce it to approximately the same temperature as that of the hot water leaving the heater. An illustrative example will be given

Example.—How many pounds of steam at 15 lb. per square inch gage pressure will be required to heat 30 gal. of water from 50 to 150° F.?

Solution.—In Eq. (2), $Q = 30$, $T_1 = 150$, $T_2 = 50$, $C_1 = 1{,}158.3$, $C_2 = 150.3$, therefore,

$$P = \frac{(8.3)(30)(150 - 50)}{32 + 1{,}158.3 - 150.3} = 23.9.$$

The approximate horsepower of a boiler to supply steam is equal to $P \div 30$.

97. Mixing Steam and Water.—One of the most economical methods of heating water by steam is to discharge the steam directly into the water, in a closed tank, through a perforated pipe, preferably of brass. The size of the steam pipe should be such as to allow a velocity of steam of about 6,000 ft. per minute, or higher, and the openings through which the steam passes into the water should have an area of about eight times the cross-sectional area of the steam pipe. An objection to this method of heating water arises from the noise created by the sudden condensation of the steam. This can be overcome by mixing air with the entering steam and arranging the discharge so that it spreads out into a cone as it rises. If the velocity of the entering steam is sufficient and the air pipe is placed in the center of the stream of steam, sufficient air will be entrained by injector action to quiet the condensation of the steam.

Devices for mixing steam, water, and air for water heating are manufactured in various capacities, as shown in Table 48. The minimum pressure at which the steam may be discharged into the tank in order to draw air in by inspiration is

$$S = \frac{H^2}{2}$$

in which S is the steam pressure in pounds per square inch and H is the depth of water in feet. Where air is mixed with the steam in a closed tank an air relief valve or other device must be provided to permit the escape of the air. Devices are manu-

TABLE 48.—CAPACITY OF DIRECT-STEAM WATER HEATERS
(Steam and water mixed)

Gallons of water per hour[1] raised 100° F.	Pounds of steam required per hour at gage pressure in pounds per square inch					Diameter of steam pipe	Diameter of air pipe
	10	20	40	60	80	Inches	Inches
50	0.70	0.69	0.69	0.68	0.68	1/4	1/8
100	1.40	1.38	1.38	1.36	1.36	1/4	1/8
200	2.8	2.76	2.76	2.72	2.72	1/4	1/8
300	4.2	4.1	4.1	4.1	4.1	1/4	1/8
400	5.6	5.5	5.5	5.0	5.4	1/4	1/8
500	7.0	6.9	6.9	6.8	6.8	1/2	1/4
1,000	14.0	13.8	13.8	13.6	13.6	1/2	1/4

1 Gallon raised 100° F. = 830 B.t.u.

factured for mixing the steam and water under pressure in a small mixing chamber in silence without the addition of air. In these devices the jet of steam is broken up into very fine bubbles by a steam-spray nozzle. This mixer or heater is placed on the feed-water line to the hot-water storage tank; the arrangement being simple and compact.

98. Explosions.—When water is heated above a temperature of 39.1° F. it expands, and if heated to a sufficient degree it will form steam. The exact temperature at which steam will form is dependent on the pressure, as shown in Table 45. Provision should be made for such expansion or for the escape of steam by allowing the water or steam to escape into the cold water pipes as shown in Fig. 28, or by the provision of an expansion tank shown in Fig. 75, or a pressure-relief valve as shown in Fig. 28, or by the installation of an air-relief valve. Air-relief valves are seldom used on dwelling or small apartment-house supplies. Where not used a faucet should be placed at the highest point in the line so that air and gases can be removed from the pipes to prevent air binding. The discharge from a safety or pressure relief valve should be piped to a sink or other outlet and so arranged that the opening of the safety valve will not scald anyone.

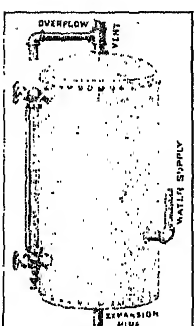


FIG. 75.—Hot-water expansion tank. (*Wm. B. Scaife and Sons.*)

Where a hard water is heated in a furnace coil, the coil may become closed or restricted by deposits of material precipitated from the water. If the pipe is not completely closed the deposits can be removed by taking the coil from the furnace and washing the coil with muriatic acid. Otherwise a new coil will be required. Provision should be made to avoid an explosion under such circumstances although the bursting of the coil and the extinguishment of the furnace fire may be unavoidable.

The development of high pressure or of steam in a water-heating apparatus represents an emergency condition only. It is not normal to proper operation, hence the most certain and simplest safety provision is the most desirable. This consists in relieving the pressure by allowing the hot water to discharge into the cold-water pipes. Among the objectionable conditions resulting from dependence on this safety provision is that the cold-water pipes may become filled with hot water or steam resulting in the scalding of some one, and the meter may be ruined.

Hot-water boiler explosions are dangerous to life and property and a plumber who installs a boiler which explodes through faulty installation may be morally and legally liable. The most obvious and inexcusable cause of explosions is the failure to provide for the expansion of the heated water, as explained above. If expansion through the heating coil into the cold-water pipe is depended upon, an explosion will probably result if the coil becomes plugged. Even with a full equipment of properly operating safety valves and provision for expansion into cold-water pipes an explosion may result in high-pressure systems. This is explained as follows: water at atmospheric pressure boils at 212° F. but if heated under pressure, steam is not formed until the temperature rises much higher. At a pressure of 80 lb. per square inch the temperature of the water will rise to 324° F. before the water boils. This high temperature may soften lead or solder used in piping or in the construction of the boiler, thus releasing the water which, because of its high temperature, suddenly bursts into steam with explosive violence. The remedy is not to use lead or solder on hot-water lines and to pay particular attention to storage-tank strength on high-pressure lines.

Where water under high pressure is heated much over 212° F. trouble will probably be encountered when hot-water faucets are opened. The overheated water issuing from the faucet imme-

diately turns to steam, sometimes with explosive violence, and probably with sufficient force to scald the operator of the faucet. Hot-water systems depending on roof-expansion tanks for pressure relief are the safest type of hot-water installation if explosions or the generation of steam in the line is to be avoided. Safety valves are sometimes used to prevent the accumulation of too great a pressure in the storage tank where check valves are used on the cold-water supply line to prevent the backing of hot water into the supply line. As previously explained, such an installation is not a thorough assurance against an explosion when the water is heated under high pressure.

The overheating of water by gas heaters can be prevented by the use of thermostatically controlled valves which cut down the flow of gas when the temperature rises above a fixed point. The overheating of water by coal heaters can be prevented by a device which opens or closes the damper on the heater when the temperature of the water is not correct. The operation of this device is dependent upon the generation of steam in it when the temperature reaches 212° F. Steam will not be generated in the heater at this temperature because of the greater pressure in the heater. The generation of steam in the device causes the closing of the damper and the cutting down of the intensity of the fire. Although the temperature of the water in the heater is higher than desirable the generation of dangerous temperatures is avoided.

99. Collapse of Storage Tanks.—The collapse of a hot-water storage tank or the siphonage of its contents as a result of the creation of a vacuum in the tank or pipes must be guarded against. Siphonage may result when the main water-supply pipe is shut off and a faucet on the supply line is opened in the basement or there is a shut-off valve of the stop-and-waste pattern below the tank. The tank may be collapsed by the vacuum created or the heating coil or the water-back may be cracked because of being emptied of water before the fire is extinguished. Danger of the collapse of a storage tank can be reduced by boring a small hole in the supply pipe near the top of the tank. This hole should have an area equal to one-fourth of the area of the cold-water pipe. The cold-water pipe should not extend down into the tank below the level of the top of the water back or heater coil so as to avoid drawing the water therefrom in the event of the siphoning of the water from the tank. The

siphonage of the tank can be prevented, also, by placing a vacuum valve on the cold-water supply pipe near to the tank or by placing a check valve on the cold-water supply pipe. Either of these devices should be installed in a building where there are faucets or other outlets on the cold-water line below the hot-water storage tank. A check valve should not be used unless some provision is made to relieve excessive pressure in the storage tank.

100. Chilled Water Supplies.[11]—In high-class hotels and other locations a continuous supply of running water chilled to between 45° and 50° F. is provided in each room or at numerous points

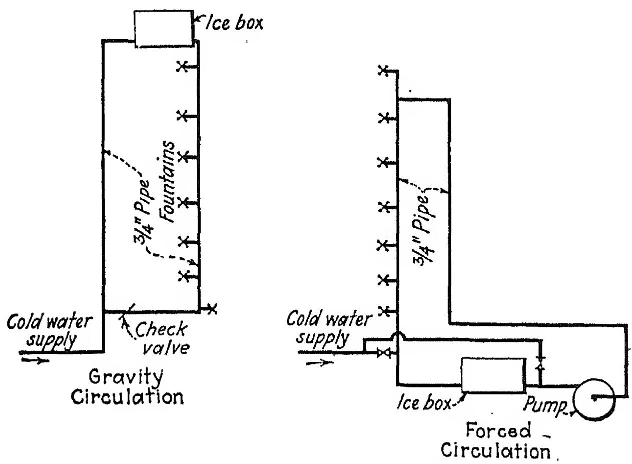


Fig. 76.—Diagram of piping arrangement for distribution of a chilled-water supply.

throughout the building. In order that chilled water may be distributed successfully provision must be made for continuous circulation of the water, or otherwise water incompletely chilled will flow from the faucet. Two installations of running chilled water which will assure continuous circulation are illustrated in Fig. 76. The pipes shown in this system are so arranged that convection currents force the continuous circulation of chilled water through the system. Such a method of circulation is not always satisfactory, however, because of the necessity for carrying ice to the top floor and because the difference in temperature between the water in the two circulating pipes is so slight as to give very little circulation. The only satisfactory circulation is obtained by means of pumps as shown by the forced-circulation

system. In some buildings it has been found more economical to chill the water in separate refrigerators on different floors rather than to circulate chilled water throughout the building.

Cleanouts and drains should be placed frequently in the pipes so that the quality of the water may be maintained at a high standard. The pipes should be covered with a heat-insulating material as described in Sec. 89 to prevent too rapid warming up, but more particularly to prevent sweating which will otherwise be a serious problem and a great nuisance. In order to secure rapid circulation the chilled-water pipes should be one or two sizes smaller than those recommended in Table 33.

The cooling of the water is effected in refrigerators which are cooled either by ice or refrigerating machines.

101. Refrigerators.—Refrigerators using ice for cooling water differ but little from refrigerators for other purposes except that coils of water pipe are placed in them and these coils must be protected against the hard usage resulting from the placing of ice around or near to them. The construction of the refrigerator box does not fall within the field of the plumber but he should be acquainted, in a general way, with the requirements of a successful refrigerator.

Substantial construction, freedom from leaks, and thorough heat insulation are the prime requisites of a refrigerator. Flimsy construction will not stand the hard knocks resulting from the handling of the ice. The box should be built with double walls, 4 to 6 in. apart, the space between being filled with charcoal, cork, or other satisfactory insulating material. Care should be taken to make the box insect proof as the insulating material makes a most desirable home for bugs. If the tank is built of wood it should have a water-tight metal lining of lead (8 lb. per square foot) or copper or zinc (16 oz. per square foot).

A section of a refrigerator for cooling water is shown in Fig. 172. Boxes in which the pipe coils surround the ice compartment are slightly larger than the type shown in this figure and are in successful use. The cooling coils should be immersed in ice water; the overflow from the box being placed so that water is drawn from the bottom of the ice compartment because the coolest water is at the top. A drain pipe should be placed at the lowest point in the box to permit the drawing off of all water. It makes little difference how the cooling coils are run so long as they are in contact with the ice water and that they are on such a

slope that they can be drained. Block tin is the best material to be used for such coils; copper and lead should not be used because of the long time in which the water may stand in contact with the metal. Iron is not dangerous but it may impart rust to the water.

The size of the box, the length of the pipe in the coils, and the amount of ice to be used depend upon the amount of chilled water to be supplied and the temperatures of the incoming and the outgoing water. Hence, only the most general recommendations for minimum requirements can be given. An increased demand for water on an excessively hot day may increase the ice consumption three- or fourfold, requiring frequent replenishment of the ice supply. For each drinking fountain supplied there should be 3 cu. ft. of space in the ice compartment and 3 cu. ft. of space about the coils. For a small fountain infrequently used allow 2½ sq. ft. of interior coil surface in the cooling chamber; for a more frequently used fountain use 9 sq. ft.; and for a fountain subject to heavy demand use 15 sq. ft. Eight ft. of 1-in. pipe will expose about 2½ sq. ft. of interior surface. From 50 to 150 lb. of ice will be used per day per fountain supplied. 100 lb. of ice will cool about 50 gal. of water from 75° to 45° F. It is not practicable to cool water below 40° F. with ice.

In parks and other out-door places the water can be cooled in an underground pit lined with concrete or brick and provided with drainage. Such pits are more economical than iceboxes in construction and in the consumption of ice. The capacity of the pit should be based on the same principles as are given for iceboxes.

Refrigerating machines operating on the principles described in Sec. 303 may be used in the place of ice-cooled refrigerators. They are proving more satisfactory and more economical except in temporary installations.

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CHAPTER VII

WATER TREATMENT

102. Purity of Public Water Supplies.—Supervision of public water supplies by state and municipal boards of health assures to the consumer a safe drinking water from most public supplies. There are, however, public water supplies which are known to be unsafe for drinking, and potability is not the only desirable quality of a water supply. It should be suitable for washing, bathing, and industrial purposes as well as for drinking. It is sometimes necessary, therefore, to purify water supplies from either public or private sources.

103. Methods of Purification.—The safest and least expensive methods of purifying water for drinking is to boil it for at least 15 min. As this method of treatment is uneconomical for public water supplies and is not always convenient for even the smallest of private supplies, some other method which will deliver a continuous supply of pure water would be more popular if not too expensive. No such method or device which will be safe and certain for all conditions of household or other intermittent service is available. Devices which are used with some satisfaction, however, include charcoal filters, porous earthenware filters, ultra-violet-ray machines, ozone machines, and chlorine or iodine tablets. The tablets are of little interest to the plumber as no device requiring installation or maintenance is connected with their use.

104. Household Filters.—A charcoal filter for domestic use is illustrated in Fig. 77. This filter is particularly applicable to use under a rain-water leader. The charcoal should be ground to a size of about ¼ to ½ in. Water will be too slow in passing through smaller pieces and larger pieces may permit the passage of unfiltered water. A filter about 12 by 24 in. in plan and 30 in. deep, constructed as shown in Fig. 77, is satisfactory for a 4-in. rain leader. Upward filtration is better than downward filtration since decomposing organic matter does not mat on the surface, the tendency to force it through the filter is less, and the

filter is more easily cleaned. The filter is cleaned by removing the cover and pouring boiling water into it from the top. Large particles of matter can be removed from the filter through the hand hole at the bottom. Suspended matter and apparently some colloidal matter is removed from the water in passing through the filter, in contact with the charcoal, so that it issues from the filter clear and sparkling. The percentage of removal of bacteria by such a filter is very low and its value as a safeguard

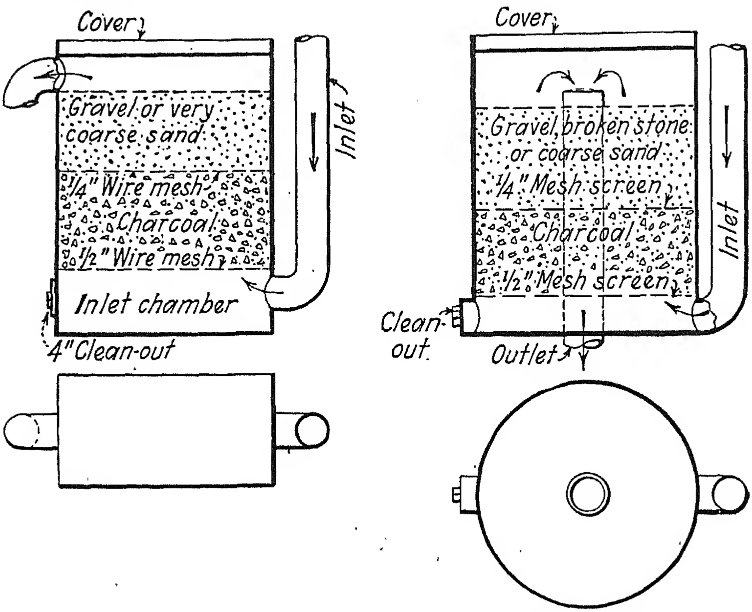

FIG. 77.—Transparent view through charcoal rain-water filters. (*C. D. Puckett, Metal Worker, p.* 491, *Apr.* 18, 1919.)

to health is inconsiderable. Small-sized charcoal filters are available which can be fastened to the end of a faucet.

The stone filter, shown in Fig. 78, is effective in removing bacteria and in removing visible particles of sediment. It does not affect color and it may have but slight effect on turbidity. Like the small charcoal filters, it may be attached to the threaded end of a faucet and water drawn from the faucet at any time. An objection to these small filters is that unless they are cleaned and boiled frequently they become foul and putrid and serve as a breeding place for bacteria and other low forms of life. They are suitable only for household supplies. Their capacity is generally

limited to a flow of 2 to 3 gal. per minute. The filtering material must be renewed whenever the appearance of the water demands it. This may mean daily or more frequent cleaning.

105. Ultra-violet Ray.—The ultra-violet-ray machine is an effective means for killing bacteria, and if clear water is passed through it the water will be sterilized. The machine will have

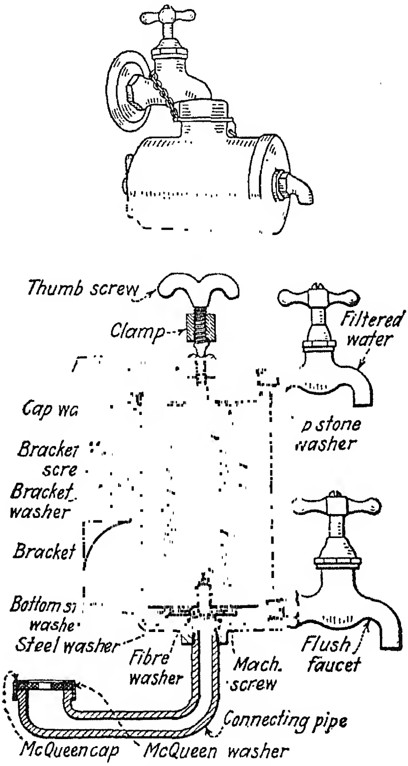

FIG. 78.—Stoneware household filters. (*Roberts Filter Co.*)

no effect in removing particles of suspended matter nor in clarifying nor decolorizing the water. The conditions necessary for the successful operation of the sterilizer are that all of the water shall flow in a thin, clear, film close to the sterilizing ray. The water should be well agitated (but not mixed with air) and the exposure to the ray should be continuous.

Ultra-violet-ray machines are used for institutions, office buildings, and particularly for sterilizing water for swimming pools.

Their popularity lies in the absence of chemicals and the lack of effect on the taste or chemical quality of the water.

The amount of current consumed is dependent on the type of machine and whether one or a number of machines are used in series. A single machine can be expected to consume about $\frac{3}{8}$ kw. in passing 120 gallons of water in 1 hr. Two larger machines in series consumed 1.54 kw. in an hour while delivering 3,000 gal. of water.[2] The success, effectiveness, and durability of these machines have been demonstrated by their use.

106. Ozone.—Machines for ozonizing water supplies have not been generally introduced and have found but little use. Not much is known about them at present so that their installation would be little more than an experiment.

107. Sand Filters.—Filtration of water through sand is accomplished in either gravity or pressure filters. The former are used almost exclusively for the treatment of public water supplies. The principal objection to their use for private water supplies is the necessity for pumping the filtered water after filtration because the water must flow by gravity from the bottom of the filter into the collecting basin, called the clear-water basin. Although gravity filter units are less expensive than pressure filters, the cost of the pump and the pumping usually renders their use uneconomical for private installations, particularly where all pressure necessary for distributing the water is supplied by the public waterworks. The rate of filtration through a gravity or a pressure filter, where a high degree of purification is desired, should not exceed 2 gal. per square foot of filter surface per minute.

Gravity filters are usually of such sizes that they are constructed in place with concrete walls and bottom and with dimensions and capacities determined by the designer. Pressure filters are made of metal resembling a boiler or hot-water storage tank, and they can be obtained only in such capacities and dimensions as are available on the market. The sizes and capacities of pressure filters, as recommended by the Filter Standardization Committee of the American Society of Mechanical Engineers, December 1916, are shown, together with other information, in Table 49.

A section through a pressure filter is shown in Fig. 79. It operates as follows: untreated water passing into the filter is dosed with a solution of aluminum sulphate (alumn) for the purpose of causing a gelatinous precipitate which will coagulate

the suspended matter in the water. The dose is arranged to apply about 1 to 2 gr. of alum per gallon of water treated, dependent on the turbidity, alkalinity, and other qualities of the water. The quantity of the dose of alumn is usually regulated by an

Table 49.—Capacities of Pressure Filters
(Filter Standardization Committee, Am. Soc. Mechanical Engineers, p. 425, 1917)

Inside diameter inches	Capacity, g.p.m.				Size of inlet and outlet pipe, inches	Inside diameter, inches	Capacity, g.p.m.				Size of inlet and outlet pipe, inches
	Rate, gallons per square foot per minute						Rate, gallons per square foot per minute				
	2	3	4	5			2	3	4	5	
	Per cent bacterial removal						Per cent bacterial removal				
	97[1]	[2]	95[3]	[4]			97[1]	[2]	95[3]	[4]	
12	1½	2⅓	3	4	......	48	25	38	50	63	2½
14	2	3	4	5	......	54	32	48	64	80	2½
16	2¾	4¼	5½	7	......	60	40	50	80	99	2½
20	5	7	10	12	......	72	57	85	114	142	3
24	7	10	14	17	......	84	77	115	154	192	4
30	10	15	20	25	1½	96	100	150	200	250	4
36	15	21	30	36	1½	120	157	235	314	392	6
42	20	29	40	49	2						

[1] Probable best possible results.
[2] Refiltration, swimming pools, etc.
[3] Clarification, 95 per cent iron removal.
[4] Removal of suspended matter.

automatic apparatus. This water, which has been dosed with alumn, enters the filter at the top and passes through the sand leaving its suspended matter and some of its dissolved impurities on the surface of and in the sand bed. The water passes through the manifold and laterals of the collector system in the bottom of the filter and thence into the effluent pipe which is connected to the distributing pipes of the building. The deposition of the impurities on and in the sand bed clog the filter, requiring more pressure to force the water through. When this pressure reaches about 15 ft. the filter should be washed. This is done by stopping the normal process of filtration and forcing clean water upwards through the sand. The dirty water from this process of washing is run to the sewer. The filter should be

washed from 5 to 8 min. at a rate of about 15 gal. per square foot of sand surface per minute. The manipulation of the valves for filtering and washing has been so simplified on some machines that only one handle need be turned when it is desired to wash the filter or to throw it back into service.

In washing, the pressure of the wash water should be about 15 lb. per square inch. The filter should be washed until the wash water comes off clear and free from suspended matter. Washing must not be done too vigorously because of the danger of removing sand, nor too long because of the waste of water, nor too slowly as this will be of no value. In some installations

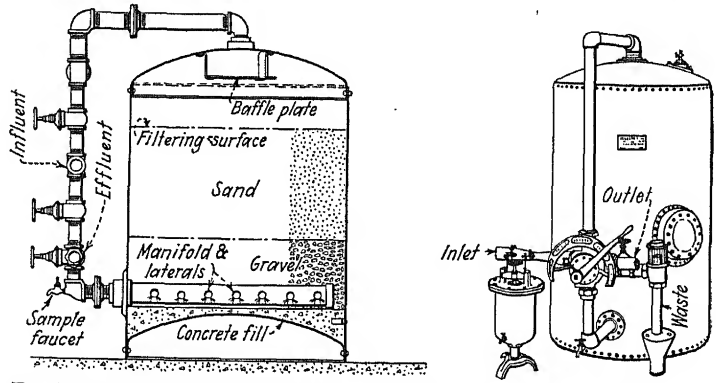

FIG. 79.—Section and exterior view of pressure filter. (*Roberts Filter Co.*)

it is proper to wash the filter with unfiltered water but where high bacterial removal is desired only filtered water should be used in washing. This may require the use of a storage tank which has a capacity of not less than 5 per cent of the amount of water filtered in 1 day. The filter should be washed at least daily. When properly maintained the sand need never be removed. The loss of pressure through these filters varies between 6 in. when the filter is clean, up to 10 to 12 ft. or more just before it is cleaned. The loss of head, or difference in pressure, between the inlet and outlet should not be allowed to exceed 10 to 12 ft. because of the packing of the sand layer and danger of breaking through it, resulting in the delivery of unfiltered water.

Information concerning the dimensions, connections, care, and operation of any particular filter must be obtained from the manufacturer, as no standards for these factors have been adopted. The amount of attention necessary for their operation

and their cost limits their use to industrial plants, institutions, and expensive residences.

108. Water Softening.—Water is made hard primarily by the solution in it of carbonates and sulphates of calcium (Ca) and Magnesium (Mg). The chlorides and nitrates of calcium and magnesium are effective to a lesser degree in causing hardness. The total hardness is the sum of all the compounds in the water which cause hardness in it. Total hardness is expressed in various ways, the standard method in American Waterworks practice being in parts per million, by weight, in terms of calcium carbonate ($CaCO_3$). The relation between the various recognized methods for expressing total hardness is shown in Table 50. The relative hardness of various waters are expressed approximately in Table 51.

TABLE 50.—RELATION BETWEEN METHODS OF EXPRESSING HARDNESS OF WATER

	Parts per million	Grains per gallon	Clark degrees	French degrees	German degrees
Parts per million	1.0	0.058	0.07	0.1	0.056
Grains per gallon	17.1	1.0	1.20	1.71	0.96
Clark degrees	14.3	0.83	1.0	1.43	0.80
French degrees	10.0	0.583	0.7	1.0	0.56
German degrees	17.8	1.04	1.25	1.78	1.0

TABLE 51.—RELATIVE HARDNESS OF WATER

Relative hardness	Extremely soft	Very soft	Soft	Moderately soft	Moderately hard	Hard	Very hard	Excessively hard	Too hard for use
Parts per million carbonate of lime	15	30	45	90	110	130	170	230	250

A simple method for determining the approximate hardness of a water is to determine the least quantity of a standard soap solution which, when shaken vigorously with a definite quantity of the water, will create a lather which will last for at least 5 min.

The soap solution should be made according to the "Standard Methods of Water Analysis" of the American Public Health Association, and the standard procedure for making the test should be followed to obtain quantitative results. The procedure requires that 50 cc. of the water to be tested shall be measured into a 250-cc. bottle. The soap solution should be added in small quantities of 0.2 to 0.3 cc. at a time, shaking the bottle vigorously after each addition. When the lather produced lasts at least 5 min. the amount of soap solution used is observed and the total hardness of the water expressed as parts per million (p.p.m.) of calcium carbonate. This can be read from Table 52.

TABLE 52.—TOTAL HARDNESS IN PARTS PER MILLION OF CALCIUM CARBONATE ($CaCO_3$) FOR EACH TENTH OF A CUBIC CENTIMETER OF SOAP SOLUTION WHEN 50 CUBIC CENTIMETERS OF THE SAMPLE OF WATER IS TESTED

Cubic centimeters of soap solution	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.0	....	....	....	....	....	....	....	0.0	1.6	3.2
1.0	4.8	6.3	7.9	9.5	11.1	12.7	14.3	15.6	16.9	18.2
2.0	19.5	20.8	22.1	23.4	24.7	26.0	27.3	28.6	29.9	31.2
3.0	32.5	33.8	35.1	36.4	37.7	39.0	40.3	41.6	42.9	44.3
4.0	45.7	47.1	48.6	50.0	51.4	52.9	54.3	55.7	57.1	58.6
5.0	60.0	61.4	67.9	64.3	65.7	67.1	68.6	70.0	71.4	72.9
6.0	74.3	75.7	77.1	78.6	80.0	81.4	82.9	84.3	85.7	87.1
7.0	88.6	90.0	91.4	92.9	94.3	95.7	97.1	98.6	100.0	101.5

Hard water is undesirable because of the amount of soap which must be dissolved before a lather can be produced.* The soap curd makes washing of clothing difficult and is objectionable in shampooing. Hard water is also undesirable in industrial supplies and in hot-water supplies because of the scale which is formed on heating surfaces and pipe lines, foaming in steam boilers, injury to fine fabrics in laundries, injury to certain manufacturing processes, such as dyeing and paper making, and for other reasons. The softening of water is more essential for indus-

* Approximately 13 oz. of soap would be required to produce a lather in 100 gal. of water with 100 p.p.m. total hardness.

trial uses than for domestic purposes. Any water containing more than 150 p.p.m. of hardness can be softened economically.

The hardness produced by the carbonates of calcium and magnesium, known as temporary hardness, can be removed by boiling. In the process of boiling dissolved carbon dioxide is driven off and the minerals, which are soluble in water only in the presence of dissolved carbon dioxide or carbonic acid gas, are precipitated. The precipitated minerals form the familiar scale on teakettles and the inside of hot-water pipes. The sulphates of calcium and magnesium cause what is known as permanent hardness. Some chemical must be added to throw them out of solution.

Municipal and large water supplies are softened by the addition of lime (CaO) or sodium carbonate (Na_2CO_3) to the water. These chemicals produce the following reactions:

I.	CaO	+	$2H_2CO_3$	=	$Ca(HCO_3)_2$	+	H_2O
	(Lime insoluble)		(Carbonic acid)		(Calcium bicarbonate. Soluble. Causes hardness)		(Water)

II.	$Ca(HCO_3)_2$	+	$Ca(OH)_2$	=	$2CaCO_3$	+	$2H_2O$
	(Calcium bicarbonate. Soluble, "Temporary hardness")		(Calcium hydroxide. Hydrated lime)		(Calcium carbonate. Insoluble)		(Water)

III.	$CaSO_4$	+	Na_2CO_3	+	H_2CO_3	=	$Ca(HCO_3)_2$	+	Na_2SO_4
	(Calcium sulphate. Soluble "Permanent hardness")		(Sodium carbonate. Soda Ash)		(Carbonic Acid)		(Calcium bicarbonate. Soluble. Gives temporary hardness)		(Sodium sulphate remains in solution, does not cause hardness)

Reaction I above expresses the conditions which occur in nature to cause hardness. Reaction II is the reaction which occurs when temporary hardness is removed by the addition of lime (calcium hydroxide). Reaction III is the reaction which occurs when permanent hardness is changed to temporary hardness by the addition of soda ash (sodium carbonate). The amount of lime or sodium carbonate necessary to complete these reactions

is dependent upon the amount of calcium and magnesium dissolved in the water. An operator, with some knowledge of chemistry, is required to give constant attention to devices using lime or soda ash or both to soften water. Such softeners are usually operated similarly to a gravity water filter. The method is, therefore, not available for household use, nor for many institutional and industrial water supplies and is not of special interest to the plumber. Domestic, institutional, and industrial supplies can, however, be softened by zeolite water softeners which are available on the market and are in extensive and successful use.

109. Zeolite Softeners.—A zeolite is any chemical compound so imperfectly bound together that it will change its composition dependent on the concentration of certain other chemicals in solution in its presence. The sodium zeolite, $NaAlSiO_4.3H_2O$, known as permutit, will exchange the sodium or magnesium for calcium when in solution in their presence and will take on the form $CaAlSiO_4.3H_2O$. When the latter compound is placed in a solution containing a greater concentration of sodium the sodium replaces the calcium and we have the original zeolite.

The zeolite salt, as used in water softeners, has the appearance of a coarse-grained sand with even-sized, hard, lustrous grains. It will absorb moisture from the atmosphere and must, therefore, be stored in dry places.

In practice, hard waters containing both temporary and permanent hardness are passed through a layer of zeolite at a temperature not to exceed 100° F., so as not to injure the zeolite. Calcium and magnesium are absorbed by the zeolite and are exchanged for sodium which goes off in solution in the water, but the presence of sodium in solution does not cause hardness. The water is partly filtered in passing through the softener and its hardness is reduced to *zero*. Upon the exhaustion of the zeolite the flow of hard water is cut off and a solution of sodium chloride (common salt) is passed into the softener and allowed to stand in contact with the zeolite. The sodium in the brine replaces the calcium and magnesium in the zeolite, which is thus restored, and the calcium and magnesium are discharged into the sewer with the wash water as calcium and magnesium chloride, together with such detritus as may be washed off of the filter. The zeolite is now ready for use for softening more water and the process can be carried on indefinitely without renewing the zeolite. In practice it can be anticipated that about 5 per cent

of zeolite will disintegrate and wash away annually. The only expense in connection with the operation of such a softener is the cost of a small amount of common salt.

A sectional view of a household zeolite water softener is shown in Fig. 80. The size of the softener to be used depends on the amount of water to be treated and its hardness. A softener which is adequate for its purpose should operate for 1 week or

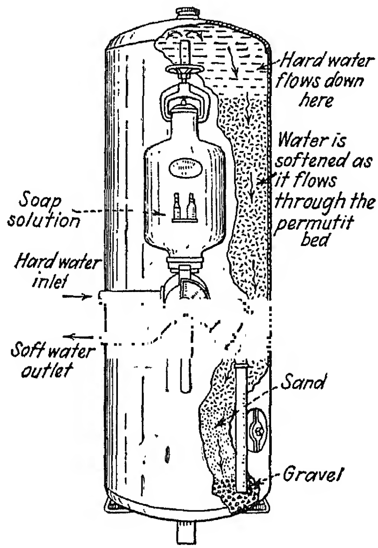

FIG. 80.—Zeolite water softener. (*Permutit Co.*)

10 days without regeneration. It should never be operated after it is depleted without regeneration as the softening material may be permanently injured. The rate of softening, regardless of the hardness of the water, lies between 75 and 120 gal. per square foot of surface of zeolite material per hour, the thickness of the zeolite bed being about 2 to 3 ft. The thicker the bed the greater the permissible rate of softening but a rate of over 120 gal. per hour per square foot of surface is undesirable because of the high velocity through the bed which may prevent all of the water coming in contact with the zeolite grains for a sufficient length of time. The hardness of the water affects only the period between regeneration; it is not a factor in determining rate of filtration but, of course, a low rate should be used for hard waters to lengthen the period between regeneration.

Where a single-unit zeolite water softener is installed a by-pass should be provided for use during the time that the softener is being regenerated and for emergency use. In a residential installation the garden-hose connection is by-passed and sometimes the fixture flush tanks are supplied with hard water.

The fact that regeneration is necessary is determined by a soap test. It is made according to particular directions dependent on the quality of the soap solution used. In general, a known small quantity of soap solution (about 3 drops) is put into a bottle containing a small quantity (about 1 oz.) of the water to be tested. The two are shaken together vigorously. If a froth or bead exists on the surface of the water for at least 5 min. it is not necessary to regenerate the softener. If the bead does not endure the softener should be regenerated. In regeneration the softener is shut off from the hard-water supply. It is then slowly flooded with a solution of sodium chloride, salt solution or brine, allowing 3 or 4 hr. for the solution to enter the chamber. The salt solution is made up with a strength of about 10 per cent sodium chloride and it is allowed to stand in contact with the zeolite for about 4 hr. In large softeners it is economical to raise the temperature during regeneration to about 100° F. After standing for this period the softener is thoroughly flushed out to remove all traces of sodium chloride and is then returned to normal service.

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CHAPTER VIII

TRAPS IN DRAINAGE SYSTEMS

110. Purpose of Traps.—The primary purposes of a trap* are to prevent the passage of air, odors, or vermin through it from the sewer into the building. The trap must also be self-cleansing, that is, it must permit the passage of water carrying solids in suspension without retaining the solids and becoming clogged. The two requirements work against each other in design since the more complicated the passages the better will the trap maintain a seal but the more likely is it to become clogged. The requirements of a "perfect trap"[1] are stated as follows:

1. It must be able to pass sewage freely without mechanical aid.
2. It must be able to prevent a passage of sewer gas either way whether sewage is flowing or not.
3. It must be self-cleansing.
4. It must have a seal deep enough to be a positive barrier to sewer gas, preferably not less than 2 in. deep.
5. It must be strong and water- and gas-tight.
6. It must have no mechanical or moving parts.
7. It should be provided with a trap screw or other means of access to the interior in the event of chokage.
8. It must have no recesses, cavities, or pockets which cannot be scoured by the flow of sewage through the trap.
9. It must have no internal projections to catch and hold hair, lint, bits of matches, etc. but must have a smooth inner surface every part of which is automatically scoured by the flow of sewage through the trap.
10. It must not have washers, gaskets, or packings on the sewer side of the seal which may decay and cause sewage or sewer gas leakage.
11. Where necessary it must be back vented.
12. It must not have concealed partitions, tubes, or other invisible parts if defects in construction may permit sewer gas to enter a house.

111. Types of Traps.—Types of traps in use on plumbing fixtures are shown in Fig. 81. Such traps are made of lead;

* Traps for special purposes such as grease traps, sand traps, etc. are described in Chap. XVII.

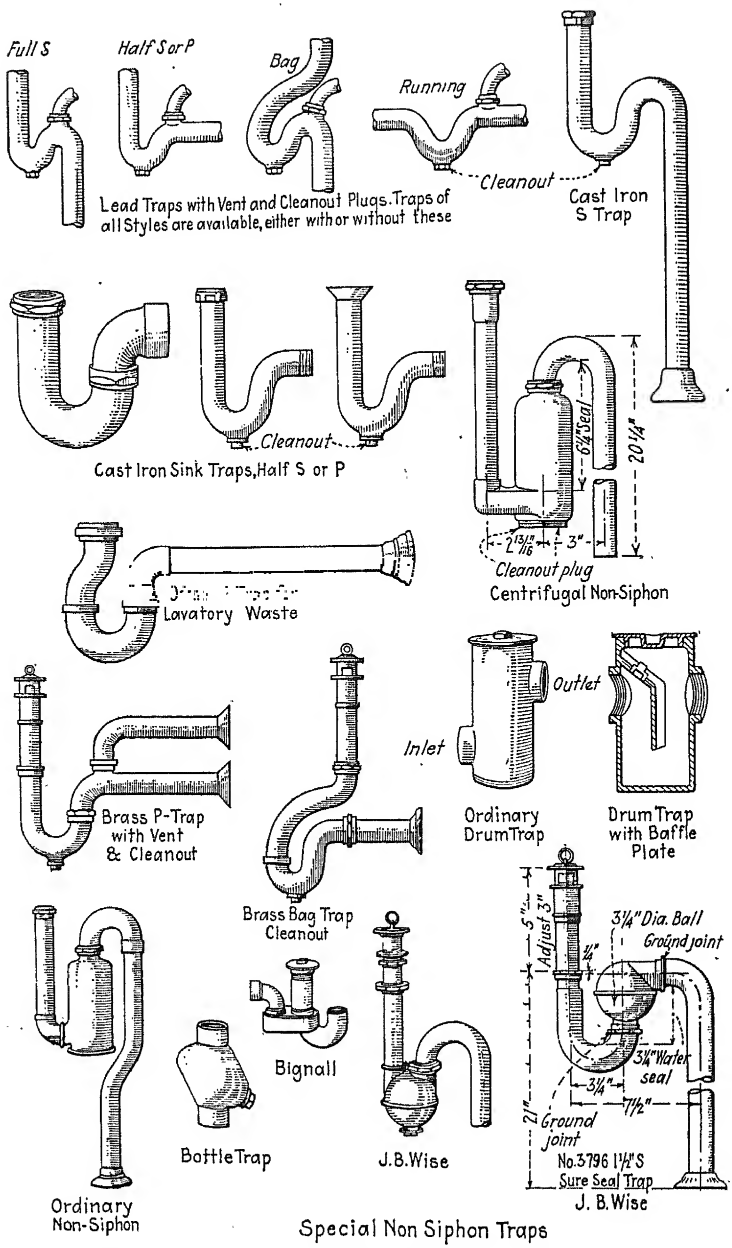

Fig. 81.—Types of traps used on plumbing fixtures. For bell traps, ball traps, etc., see Figs. 150 and 151.

brass, either plain or nickel plated; wrought metal, either plain or galvanized; and cast-iron, either plain or galvanized. Lead traps are manufactured in three different weights, as shown in Table 53. The recommendations of the Division of Simplified Practice of the U. S. Department of Commerce concerning brass lavatory traps are given in Appendix I, Sec. 19. The "elements" of a trap are shown in Fig. 204.

TABLE 53.—WEIGHTS OF PLAIN LEAD TRAPS, P, S, BAG, AND RUNNING
(Manufacturer's standard, pounds per foot)

Diameter inches	Standard	Medium	Extra heavy
1¼	1½	2	2½
1½	2¼	3	3½
2	3¼	4	4½
3	5	4¾	6
4	6	6	8

So-called non-siphon traps[2] have been designed with the purpose of creating traps with stronger seals than those found in simple traps. Some types of non-siphon traps are illustrated in Fig. 81. It is to be noted that five different principles are involved in increasing the strength of seal in such traps:

1. The depth of seal is increased.
2. The volume of water retained is increased.
3. The passages are made more tortuous.
4. The water is given a whirling motion in passing through the traps.
5. Moving parts are depended upon to prevent the back flow of water.

Each of these expedients will increase the strength of the seal but all but the fourth are objectionable because of the increased tendency for the trap to clog.

The strength of the seal of a trap is closely proportional to the depth of the seal. This has been demonstrated in the tests at the University of Illinois, and is discussed in more detail in Sec. 117. Unfortunately, the increase of depth of seal increases also the probability of solids being retained in the trap and a limit of about 4 in. depth of seal for traps which must pass solid

matter has been placed by some plumbing codes. The depth of seal most commonly found in simple traps is between 1½ and 2 in. The Hoover Report recommends a minimum depth of 2 in. as a safeguard against seal rupture and a maximum depth of 4 in. to avoid clogging, fungus growths, and similar difficulties. Traps in rain-water leaders and other pipes carrying clear-water wastes only and which are infrequently used should have seal depths equal to or greater than 4 in.

The increase in the volume of water retained in the trap helps very little in increasing the strength of the seal but it does materially reduce the velocity of flow through the trap so as to increase the probability of sedimentation of solids therein.

The evaporation of water from traps is a cause of loss of seal, particularly where the fixtures are seldom used. The principal factors affecting evaporation are velocity of air movement, per cent of moisture in the air, the area of water surface exposed, and temperature. The factors are so variable between different installations and so little authentic information is available that, in practice, it is usually considered that 1 in. of water will evaporate in 3 weeks from an unvented trap, and twice as much in the same time in a vented trap. Non-siphon traps, such as drum traps, with only a small surface exposure compared with the volume of water in the trap will lose their seal much less rapidly, retaining it for 6 mo. to a year in the most favorable circumstances.

The increase in the volume of water in a trap will, therefore, help to minimize seal loss from evaporation. Traps with large volumes of retained water can, therefore, be used with good results on such locations as rain leaders, floor drains carrying no solid matter, safe wastes, etc.

The bell trap, shown in Fig. 162, is used most commonly on floor drains. Its use is not recommended under any conditions as it is not a simple form of trap and its seal depends upon the perfection of a single casting. Its use in floor drains is advantageous only when the thickness of the floor is insufficient to permit the installation of some more desirable form of trap.

The creation of tortuous passages by baffling is probably the most effective method of increasing the strength of trap seals but it is objectionable because of the greater difficulty for solids to pass through the trap and because in the construction of such traps it is difficult to avoid leaving holes in the baffles thus

permitting the passage of gas through the trap. Such traps are almost universally prohibited by plumbing ordinances.

Traps with moving parts are available on the market. A ball trap is shown in Fig. 162. They have the advantage of a certain and permanent seal, when they work properly, but the disadvantage of not being self-cleansing and occasionally failing to close properly. Such traps are prohibited in a large number of plumbing codes because of the uncertainty of their operation.

All traps should be provided with cleanout openings conveniently located and no trap should be placed inaccessibly. The cleanout openings are evident in most of the traps illustrated in Fig. 81. Standard dimensions of brass lavatory and sink traps are shown in Table 146.

112. Materials and Construction of Traps.—Traps for bathtubs, lavatories, sinks, and other similar fixtures should be of lead, brass, cast iron, or malleable iron which is either galvanized or which has been lined on the inside with porcelain or similar substance. Traps should have a full bore, smooth interior waterway with threads tapped out of solid metal.

113. Non-siphon Traps.—Any trap in which the diameter is not greater than 4 in. and the depth of seal is between 3 and 4 in., and in which the volume of water held back in the trap and waste pipe is not less than 1 qt. may be classed as a non-siphon trap. A satisfactory non-siphon trap is one which offers greater resistance than is offered by a simple trap to the breaking of its seal by siphonage, but at the same time is not subjected to clogging and is easily cleaned. Types of non-siphon traps are discussed in Sec. 111.

114. Undesirable Forms of Traps.—Traps which depend upon movable parts or concealed interior partitions are generally considered undesirable because of the danger from the blocking open of the movable part or from holes appearing in the partitions. Likewise, traps having covers over hand holes on the sewer side of the trap which are held in place by lugs or bolts are not always desirable because of the danger from leakage through such covers.

115. The Movement of Water in Traps.*—When water flows in the discharge pipes of a plumbing system waves of air pressure are created and transmitted to various parts of the system. These pressure waves cause a movement of the water in the traps

* See also Sec. 126.

connected to the system. The amount of this movement is not an accurate measure of the intensity of the pressure wave but since the change of level of the water in a trap is of more importance in plumbing design than the actual pressure, the change or difference of level between the surfaces of water in the two legs of a trap will be expressed as pressure.

The pressures produced fluctuate widely in intensity and nature and consequently the movement of the water in traps may be rapid and erratic. Observations of pressure or movement are difficult and their degree of accuracy is less than though the movements were slow and steady. The pressures are affected by

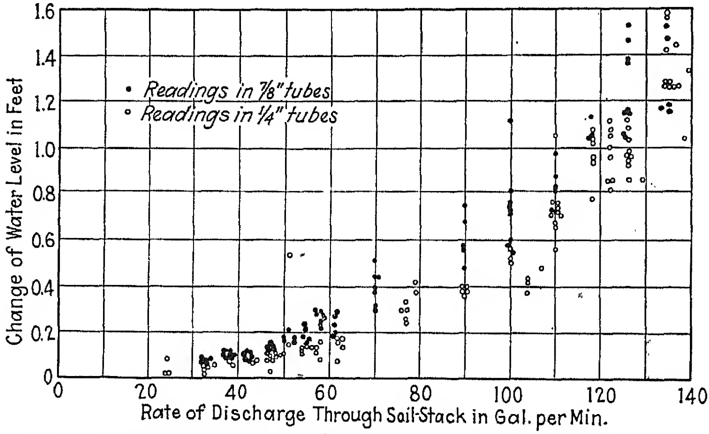

FIG. 82.—Change of water level in 1/4- and 7/8-in. U-tubes for various rates of discharge. (*From Bull.* 143, *Eng. Experiment Station, University of Illinois*, 1924.)

many different kinds of factors such as the formation of a vortex (whirlpool) as water falls down the stack, the breaking of water into a fine spray at various points in the stack, the adhering of the water to the sides of the stack in one case and falling freely down the center of the stack in another case. The result is that under apparently the same conditions the movement of water in a trap is seldom the same. In making tests it is necessary to repeat observations a number of times to be sure that the maximum movement has been observed, and conclusions should be drawn from a consideration of the minimum, the average, and the maximum observations. If there is any relation between the average of many observations of pressure and the maximum or minimum pressure it would be desirable to know this relation. Conclusions with regard to such a relation are presented in Sec. 193.

116. Seal Strength in Simple Traps.—The three important factors in determining trap seal strength are diameter, depth, and volume of seal. These will be considered and tests reported.

Diameter.—It is of value to know whether an increase or a decrease in diameter of trap, above or below those sizes now commonly used in practice, will decrease the movement of the water in the trap under the same pressures. To answer this question it would be necessary to subject traps of different diameters, but

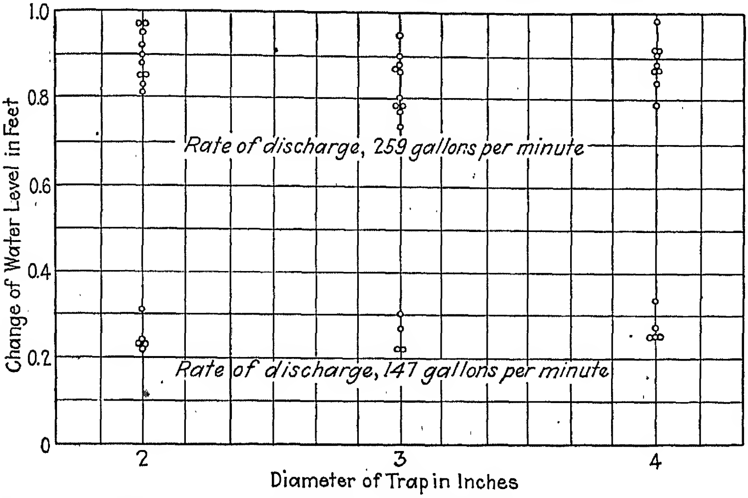

Fig. 83.—Change of water level in 2-, 3-, and 4-in. U-tubes for two rates of discharge. (*From Bull.* 143, *Eng. Experiment Station, University of Illinois*, 1924.)

with the same depth of water in them, to the same pressures. That trap in which the movement of water is the least presents the greatest resistance to rupture of its seal. Tests were made[3] on traps or U-tubes, ¼, ⅞, 2, and 4 in., in diameter. These were attached directly and without vent to a 4-in. stack down which water was discharged. Some results of these tests are given in Figs. 82 and 83.

It was concluded, as a result of these tests, that the maximum change of level of the water in a trap resulting from the application of pressure is approximately the same for all diameters of traps, provided the diameter is sufficiently large to render negligible the effect of friction in retarding the movement of the water. The minimum diameter of trap to satisfy this condition seems to be about 1 in. From a practical standpoint it is undesirable to decrease the diameter of those traps now in common use

because of the resulting difficulties from clogging and the slower emptying of the fixtures. The tests show that an increase in the diameter of the traps will not effectively increase the strength of the seal.

Depth.—It is of value to know whether an increase in the depth of water above that ordinarily used in traps will decrease the movement of the water in the trap. To answer this question it is necessary to subject traps of the same diameter, but with different

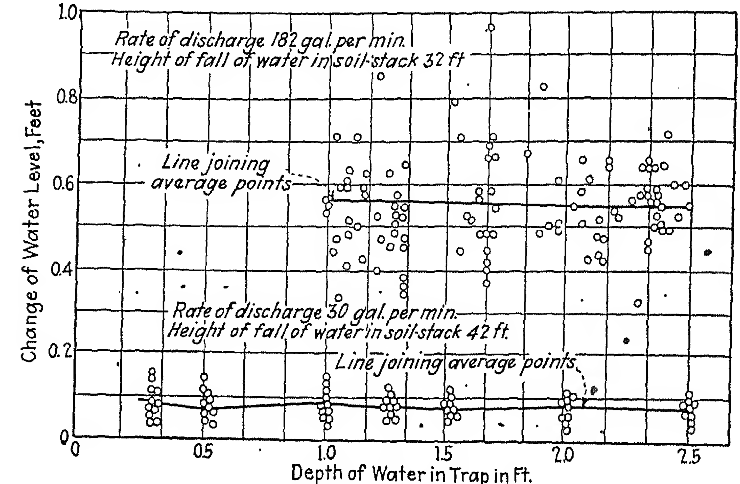

FIG. 84.—Change of water level in 2-in. U-tubes containing different depths of water for various rates of discharge and two heights of fall in the soil stack. (*From Bull.* 143, *Eng. Experiment Station, University of Illinois*, 1924.)

depths of water in them, to the same pressures. That trap in which the movement of the water is the least presents the greatest resistance to rupture of its seal. Such tests were made at the University of Illinois[3] under similar conditions to those comparing trap diameters. Some of the results of the tests are shown graphically in Fig. 84. A summary of the conclusions drawn from the tests indicates that the increase of the depth of the seal does not cut down the movement of the water in the trap.

Volume.—It follows from the preceding discussions of diameter and depth of trap seals that an increase in the volume of water in a trap will not be practicable in decreasing the motion of water in the trap.

117. Relation between Depth and Strength of Trap Seal.—The strength of the seal of a trap is measured by the intensity of

siphonage or back pressure necessary to force air through the trap. The depth of a trap seal is defined on page 439. Where a pressure is slowly developed and constantly maintained the intensity of pressure is measured by the total movement of the column of liquid, as illustrated in Fig. 85. This figure shows a manometer in which the pressure at A is equal to a column of liquid of height h. It would be necessary to produce a pressure of $2S$ at A in order to force air through the trap, provided D were equal to or greater than $2S$, *i.e.*, the intensity of pressure necessary to force air through the trap under these conditions is measured directly by the depth of seal in the trap.

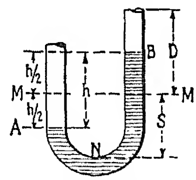

FIG. 85.—Movement of water in a trap.

Pressures in plumbing systems are not produced slowly and steadily and they are not maintained for long periods of time. On the contrary they consist of sudden impulses of short duration. A hypothetical consideration of such impulses would lead to the conclusion that a deep-seal trap would be more than twice as strong as a trap

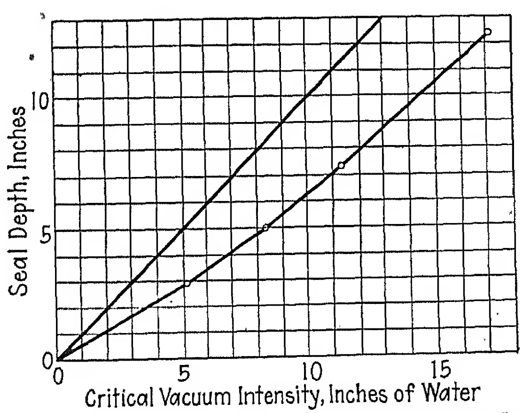

FIG. 86.—Seal depth *versus* seal strength. (*From tests made in the Eng. Experiment Station, University of Illinois. Illinois Master Plumber*, October 1925.)

with a seal of only one-half the depth because the energy of the impulse would be consumed in imparting momentum to a greater mass of water. Because of a lack of knowledge of the duration and intensity of the pressure impulses the relation between the strength and depth of a trap seal can best be determined by test.

The conclusions reached as the results of tests[3,4] are to the effect that for all practical considerations the strength of a trap seal is directly proportional to the depth of the seal, that is, it will require twice as much siphonage or back-pressure to break the seal of a trap which is 4 in. deep as the same type of trap with a seal only 2 in. deep.

The degree of inaccuracy of this conclusion is indicated by the results of a typical test illustrated in Fig. 86. If seal strength were directly proportional to seal depth the pressure line should be straight. For the depth of seals used in practice, which may be as great as 6 or 7 in. in exceptional cases in some non-siphon traps, the maximum deviation of the observed pressure line from a straight line is about 10 per cent. This deviation is much less than the deviation of one observation from the mean of many observations, and, as shallower depths of seal are compared, the percentage of deviation from a straight-line relation would be diminished.

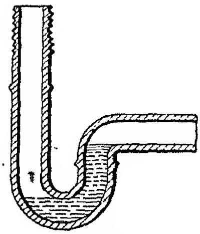

Fig. 87.

It is, therefore, concluded, both from a consideration of test results and from hypothetical considerations, that, within the limits of the depth of seal used in practice, the strength of seal is directly proportional to the depth of seal. It will, therefore, require twice as much siphonage or back pressure to break the seal of a trap 4 in. deep as the same type of trap with a seal only 2 in. deep.

Traps in plumbing fixtures seldom stand full. After a fixture has been discharged its trap may stand full, but the pressure created by its discharge will have affected all of the traps connected to the same plumbing pipe to the extent that some water will have been discharged from all traps. The question then arises; *does the removal of water from a trap weaken its seal?* Since tests have shown that within practicable limits the mass (or weight) of water in a trap is not a factor in determining the strength of seal, it is evident that so long as there is a sufficient volume of water in the trap to fill the outer leg and the lowest portion of the trap, as indicated in Fig. 87, the removal of water from a trap does not weaken its seal.

118. Comparison of Traps to Resist Siphonage.—In order to determine the effectiveness of different types of traps to resist seal rupture by siphonage (aspiration) a number of traps were

tested at the Eng. Experiment Station of the University of Illinois.[3,5] The apparatus used for testing these traps is illustrated in Fig. 88. The test was made by sealing the trap with water, then pumping any desired intensity of vacuum in the vacuum tank, and finally suddenly opening the valve between the trap and the vacuum tank. The water remaining in the

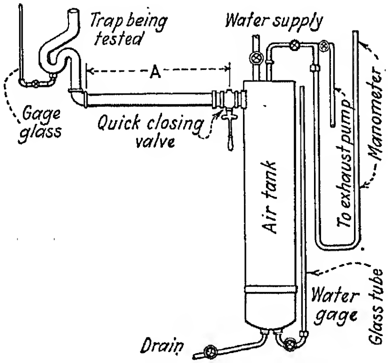

FIG. 88.—Trap-testing apparatus.

TABLE 54.—RESULTS OF TRAP TESTS
(Eng. Experiment Station, University of Illinois)

Type of trap	Size of trap, inches	Depth of seal, inches	Intensity of vacuum required to break seal, feet of water	Intensity of vacuum in feet and inches of water on basis that seal is 2 in. deep
				feet inches
P	2	1 9/16	0.42	0.54 = 6½
P	1½	2⅛	0.52	0.49 = 5⅞
P	1¼	2⅛	0.36	0.34 = 4⅛
S	2	2¼	0.52	0.46 = 5½
S	1½	2⅜	0.50	0.44 = 4¼
S	1¼	2⅜	0.38	0.32 = 3⅞
Bag	2	2¾	0.66	0.48 = 5¾
Bag	1½	2	0.48	0.48 = 5¾
Bag	1¼	2¼	0.44	0.39 = 4⅝
Drum	1½	3¼	2.50	1.54 = 18½
Non-siphon	1½	4¼	3.80	1.79 = 21½

trap, after this treatment, was measured and when the amount of water remaining indicated that the seal of the trap had been broken, the corresponding intensity of vacuum was recorded as the intensity of vacuum necessary to break the seal of the trap. The results of many of these tests are shown in Table 54.

In practice a trap may be exposed to repeated applications of vacuum, caused by the discharge of other fixtures, before the supply of water in the particular trap is renewed by the discharge of the fixture to which it is attached. The result of these repeated applications might break the seal with a much smaller

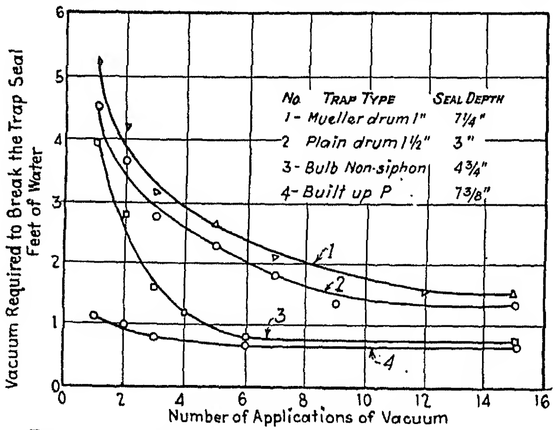

FIG. 89.—Results of repetitions of siphonage on traps. (*From tests made in the Eng. Experiment Station, University of Illinois. Illinois Master Plumber, Aug.* 1925.)

intensity of vacuum than would be required to break the seal the first time the vacuum was applied. A series of tests was made at the Eng. Experiment Station of the University of Illinois to bring light on this point.[6] A vacuum of some particular intensity was repeatedly applied to a trap without renewing the water in the trap. If, after a certain number of repetitions, the seal was not broken the intensity of vacuum was increased until the seal was broken. The results of these tests are illustrated in Fig. 89.

It should be noted, in studying the lines of Fig. 89, that all traps of the same seal depth approach the same strength in resisting siphonage regardless of the type of trap, and that the difference in strength of seal between an ordinary P trap and a complicated non-siphon trap is surprisingly small. It is to be noted also that the best type of non-siphon trap ordinarily permitted in most plumbing codes is an ordinary drum trap such as

is commonly used on bathtubs. None of the proprietary non-siphon traps, which would be permitted under the majority of codes, was so good as the ordinary drum traps in resisting siphonage.[7]

The "critical volume of vacuum" is a factor of importance in making these tests. If the volume of air in the vacuum tank is changed (below a certain volume called the "critical") the intensity of vacuum necessary to break a trap seal will also be changed. The condition is shown grapically in Fig. 90. It is evident, then, that in testing any trap the "volume of the vacuum" must always be above the "critical." The critical volume for any trap occurs where the curve, such as that shown in Fig. 90,

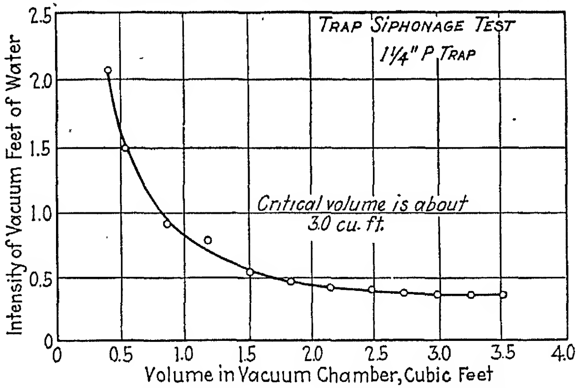

FIG. 90.—Results of test for critical volume of vacuum for a P-trap. (*From tests made in the Eng. Experiment Station, University of Illinois.*)

becomes horizontal for that particular trap. The "volume of the vacuum" in the apparatus shown in Fig. 88 was controlled by partially filling the vacuum tank with water. All tests were made with volumes of vacuum greater than the critical.

119. Comparison of Traps to Resist Self-siphonage.*—Traps may lose their seals in either of two ways; by aspiration (siphonage) or by self-siphonage. A trap well able to resist seal rupture by siphonage may be ineffective against self-siphonage. The same traps which were tested under siphonage tests were also tested against self-siphonage. The apparatus used in these tests is illustrated in Fig. 91.

120. Comparison of Traps to Resist Back Pressure.—In resisting back pressure no water is lost from the trap unless the pressure is sufficiently sudden and violent to eject the water out

* See Sec. 203.

of the fixture. After the cessation of the back pressure the water drops back into the trap again and there is no loss of seal strength. The ability of traps to resist back pressure is dependent upon the height to which water can rise in the fixture before the dip of the trap is unsealed.

Running traps will resist only one-half the back pressure of a P, S, or bag trap because the water cannot rise in the leg of the trap opposite to the pressure. Non-siphon traps will resist back pressure more effectively than simple traps because of the large volume of water available to back up into the fixture drain pipe, thus building up a high head to resist the back pressure. The comparative resistances of all traps, except running traps, against

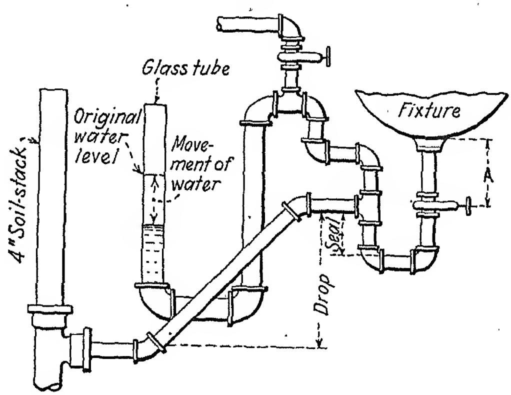

FIG. 91.—Apparatus used in self-siphonage tests of vented traps.

back pressure is, therefore, directly proportional to the volume of water above the dip in the trap divided by the cross-sectional area of the drain pipe, under the assumption that the water does not back up into the fixture.

121. Comparative Clogging Tendencies of Traps.—From a practical standpoint the plumber is interested in the ability of a trap to keep itself clean. Although the so-called "hair-pin trap" (now out of date) is very successful in maintaining its seal no reliable plumber with experience would care to use it because of its propensity for clogging. The most successful traps in keeping themselves clean are those with the straightest, smoothest passages and with the highest velocities through them. The simplest P, S, and running traps fulfill these requirements. Since they are also satisfactory in resisting siphonage and self-siphonage their use is generally to be recommended.

Where non-siphon traps must be used a drum trap with a whirling motion of the water is to be recommended as best suited under most conditions of self-siphonage, siphonage, and self-cleansing. The Hoover Report* states in reference to the tests conducted at the Bureau of Standards:

The tests have shown that "resealing" traps† when clean, retain a greater seal under a suction test and are more resistant to back pressure with the seal left after the suction test than clean, unvented, plain P traps of the same full seal depth when subjected to the same suction and pressure tests. The same is true to a lesser degree for resealing traps of the better types, fouled by artificial means.

The tests so far indicate that there is a field in which a judicious use of the better types of resealing traps would be found a distinct advantage, such as in places where there is danger of self-siphonage or of aspiration and back pressure within certain limits and where structural difficulties are encountered that make the venting of the plain trap costly or impractical. The data are not yet at hand to determine to what extent "resealing" traps may be used with safety. With data available it will be found difficult to state in a general way the extent of their use without opening a way for misuse under certain conditions. Where an unvented plain trap will serve there is no special advantage gained by the use of "resealing" traps in places where it is necessary to vent individually regardless of the kind of trap used.

122. Main or House Trap.—The main or house trap is a running trap placed on the house drain somewhere below all other connections to the house drain. Its purpose is to prevent the entrance of sewer air into the plumbing system and to avoid the use of a house plumbing system as a ventilation channel for the public sewer. That sewer air does pass into a plumbing system which is not protected by a main trap is incontrovertible. Illuminating gas leaking into a sewer has been seen to burst into flame at the top of a vent stack. Against the advantage of excluding sewer air from the building must be placed the advantage of ventilating the public sewer and the disadvantage of danger from clogging and the increased pressures in the plumbing system. The sewer air is cleaner, because of the ventilation, the dangers from explosion are reduced, and there is less danger of breaking the seal of the traps due to high pressures. Where a house trap is used the pressures can be minimized to a great extent by the installation of a fresh-air inlet. A fresh-air inlet

* Page 141.

† Equivalent of non-siphon traps.

is described in Sec. 138. The controversy over the main trap has been vigorous among sanitarians, frequently developing more heat than light. Some codes still require its use and others prohibit it. The general concensus of opinion seems to tend towards its abolition. The Hoover Report* concurs in the general recommendation for its omission.

A number of tests on house traps have been made at the University of Illinois[3] to study the hydraulic and pneumatic effects of its use. The results of some of the tests are shown graphically in Fig. 92. In view of the decided increase in back pressures shown in this figure it is evident that the presence of a house trap may contribute to the breaking of seals improperly vented. The presence of a fresh-air inlet is shown to be of only

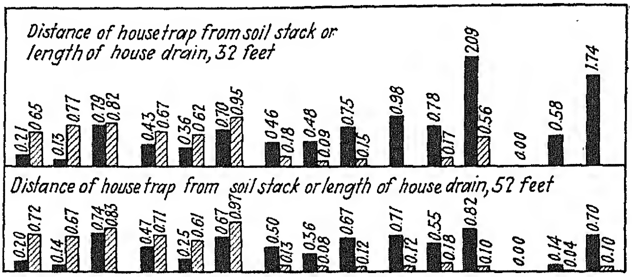

FIG. 92.—Pressures in a plumbing system with a house trap either vented or unvented, and without a house trap. (*From Bull.* 143, *Eng. Experiment Station, University of Illinois*, 1924.)

The rate of discharge was 118 gal. per minute.

slight assistance. The conclusion reached as a result of these studies is that the disadvantages of house traps outweigh their advantages and that they should not be used.

123. Location and Setting of Traps.—Traps should be set upright, level, well supported, and accessible. They should be set close to the fixture in order to avoid the exposure of foul interior surface of waste or soil pipe to the atmosphere of the room. Each fixture should be separately trapped, except that experience has shown that a battery of lavatories or laundry trays or other similar group of fixtures from which human excrement is not discharged, as illustrated at *N* in Fig. 113, may be served by a single trap. The advantage of this arrangement lies in the simplification of the waste piping, the reduction of expense, and the more frequent use of the trap will minimize the danger

* Page 202.

of seal loss by evaporation because of the frequent restoration of the seal. The disadvantage lies in the amount of untrapped waste-pipe surface which is exposed to the air of the room. Just where the limit shall be placed is a matter of judgment.

Recommendations concerning the sizes of traps are given in Table 57. These sizes are usually one nominal size larger than the outlet from the fixture in order that a slip joint may be used between the trap and the waste pipe.

Double trapping of a fixture or a plumbing system is to be avoided because of the danger from air binding. A double-trapped fixture is illustrated in Fig. 93. If the waste pipe becomes so filled with air and water that conditions arise as illustrated, the depth of water H in the fixture must be greater than h_1 in order that water may run through the discharge pipe. This may result in an overflow from the fixture or failure of the fixture to flush properly.

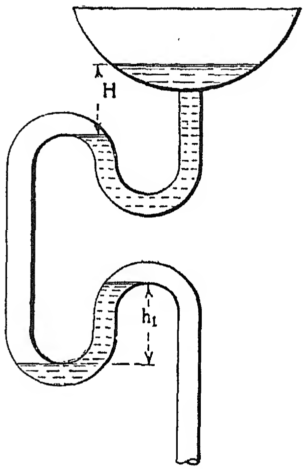

FIG. 93.—Diagram of double-trapped fixture.

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4. *Illinois Master Plumber*, p. 9, October, 1925.
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CHAPTER IX

DRAINAGE AND VENT-PIPE DESIGN

124. The General Problem.—In the design of the drainage pipes of a plumbing system it is desired to use the smallest pipes that will conduct waste water away rapidly without clogging, to place them in the most convenient location, and to avoid the production of siphonage or back pressure. Such a desire requires the solution of a number of problems involving the principles of hydraulics and pneumatics. The solution of such problems is made difficult by the lack of a precise formula to fit any assumed conditions. In the words of the report of the Subcommittee on Plumbing of the U. S. Department of Commerce (The Hoover Report):

> The fact that a plumbing system consists of many parts—the sewer, the house drain, the vertical stacks, the connections between the stacks and the house drain, lateral branch drains of various sizes, lengths, and forms, the vent system, and the water supply system—each of which may be varied independently and which are certain to be varied in practice, coupled with the fact that, in general, the pipes are only partially filled and that both the water and air movements must be accounted for, make it impracticable, if not impossible, to develop any single mathematical expression for general application. The problem of developing even a series of formulas is rendered more difficult by the failure of certain types of results to duplicate when the experiment is repeated. For example, with the simplest system, consisting of a wash basin fitted with a plain P trap and short waste open at the end there is a wide difference in results produced on the final seal of the trap when the basin is repeatedly discharged with the same quantity of water as nearly as possible in the same manner.

A resume of available data on many problems is presented in this and subsequent chapters. These data should be of value in solving specific problems encountered in plumbing design or installation. The principal sources of information on these subjects have been, "The Hydraulics and Pneumatics of House Plumbing," *Bulletin* 143 of the Engineering Experiment Station of the University of Illinois, issued in 1924, and "The Report of

the Subcommittee on Plumbing of the Building Code Committee of the U. S. Department of Commerce," known as the Hoover Report, issued in 1924.

As a result of an exhaustive series of tests on various plumbing installations in dwelling houses the Hoover Report concludes:

The results of the preceding tests in connection with other experiments justify a number of general conclusions which may safely be applied to all dwelling-house plumbing, namely:

1. The 3-in. stack is adequate for all separate dwelling-house plumbing.
2. It is possible by close grouping of the fixtures around the soil stack to obtain safe and efficient drainage for a single floor and for the highest floor of a more complex system without back venting any of the fixtures.
3. It is necessary to back vent individually or in groups all small branch waste lines directly into a stack below a water closet on the same stack to protect fully the seals of traps on such branches.
4. A back-vented side-inlet branch to a "crowfoot" fitting on a middle floor offers a degree of protection that makes it unnecessary to back vent the water closet individually, provided the possible discharge does not exceed that from one bathroom group plus a kitchen sink or 10½ fixture units.
5. In cases where the possible discharge from floors above exceeds 10½ fixture units it is necessary to back vent each separate branch individually, including water-closet branches, on a middle floor.
6. It is necessary to back vent each separate branch connected individually on the lower floor including water-closet branches, unless there is 3 ft. or more of straight stack below the fittings taking such branches, in which case the rules for a middle floor may be applied with safety.
7. In a combined sewer system it is necessary to make ample provision in the size of house drain and house sewer in order to protect fixtures set low on the stack, even when such fixtures are individually back vented.

The above conclusions are based on the assumption of the use of plain traps and with the realization that in practice considerable departure from any fixed conditions assumed for test purposes may occur.

125. Requirements of a Drainage System.—The plumbing system of a building can be divided into three parts: the water supply pipes, the fixtures, and the drainage pipes. The former bring water under pressure to the fixtures; the latter conduct the waste water and drainage away from them. The flow of water in the drainage pipes is due to gravity alone, the drainage pipes

seldom flowing full of water, and the water always flowing from a higher to a lower level. The principles of design of drainage pipes are, therefore, different from those for the design of water-supply pipes.

The drainage pipes of a plumbing system take the waste water from the fixtures and deliver it to the sewer. Since it is undesirable to permit air, odors, or vermin from a sewer to enter a building some device for preventing this must be installed and the drainage pipes must be made tight.

The requirements of a drainage system can be summarized as follows:

1. It must carry the waste water rapidly away from the fixtures.
2. The passage of air, odors, or vermin from the sewer into the building must be prevented.
3. The drainage pipes must be gas tight, air tight, and water tight.
4. The pipes must be durable and so well installed that slight movements of the building or of the pipe will not cause leakage.

The materials for the drainage system should be selected for strength and durability and to resist the corrosive action of wastes discharged into them. Ordinary drainage pipes of cast iron or wrought metal should not be exposed to acid wastes nor to steam nor hot water. Heat increases the rapidity of the evaporation of water from traps, causes the emission of foul odors, and the alternate expansion and contraction of pipes tends to loosen calked joints.

126. Pressure and the Flow through Drainage Pipes.—A brief discussion concerning what occurs when plumbing fixtures are emptied into the pipes of a plumbing system may be helpful. The manner of flow through plumbing drainage pipes differs from that through either water-supply pipes or sewers. The flow is intermittent. In the horizontal waste pipes the cross-section of the pipe may or may not be filled with water. It is not to be expected that the flow down the soil stack will be the same as that found when water feeds freely into the top of a vertical pipe in such a way that the pipe flows full as in the case of a down spout supplied with an abundance of water. Instead, at least in the case of the discharge of as much water as will come from a water closet, the first of the water to reach the soil stack from a horizontal waste pipe will have fallen some distance and gained con-

siderable velocity before the last of the discharge of the fixture reaches the soil stack. As a result air from the upper part of the soil stack is carried down with the discharging water, and the space in the soil stack occupied by the discharging water and entrained air is greater than that which would be taken by the water alone in a compact body.

The water and air in such a case occupy the full section of the soil stack and move down together and act somewhat as a long elastic piston in expelling air ahead and in drawing in air behind it. The presence of air intermingled with the falling water allows parts of the piston to expand somewhat or to be compressed slightly according as the water at the head of the piston is accelerated or retarded, and thus negative or positive pressures are created which may be transmitted to tributary waste pipes and traps. The negative pressure may be expected to develop when the first of the falling water has had sufficient opportunity to acquire a greater velocity than that of the water following it, and the positive pressure when the velocity or the leading water is retarded, as at the time it reaches the bottom of the soil stack. If there is no unvented house trap and the house drain is freely open to the passage of air to the sewer, the positive pressure formed just ahead of the discharge down the soil stack will be slight, generally of the order of one one-hundredth of a foot or less. Similarly the negative pressure immediately behind the discharge will be small if the soil stack is open at the top.

For relatively short lengths of pipe the friction of the flow of air is so slight and its mass so small that the air in the pipe is moved without much compression or expansion of its volume, and thus will readily transmit pressure or relieve it, as the case may be. For lengths of pipe relatively long with respect to the diameter, as may be the case with vent pipes, the resistance to flow may be sufficiently greater and the resulting compression or expansion of the air such that the relief afforded is insufficient for the needs. Since the relief of pressure is the prime purpose of venting traps and plumbing pipes, it is important to know the limits of length and size of vent pipe within which the relief will be sufficient to assure freedom from loss of seal in the trap.

A simple computation will show that only a small change in volume of the air in a pipe, either compression or expansion, will take place before the seal of a trap is broken. Taking normal atmospheric pressure as equivalent to 33 ft. of water, it is seen

that a seal of 2 in. corresponds to a pressure of about one two-hundredth of atmospheric pressure. A positive or negative pressure of 2 in. of water will then change the volume of the confined air only about one two-hundredth of itself.

The tests made bear out the observations given above.

When water flows in the waste pipes of a plumbing system the air in the pipes is compressed or rarefied and put in motion and thus pressures above and below atmospheric are created. An attempt has been made, in the preceding paragraph, to explain why such pressures are created. The pressures resulting from the flow cause the change of level of water in U-tubes, or traps, connected to the pipes of the plumbing system. The difference of the level of water in the traps is not an accurate measure of the pressure but since the change of the level of the water in the trap is of more importance in plumbing design than the actual pressure, and each is dependent on the other, the change or difference of level is usually recorded as the pressure.

Air pressures are not steady but fluctuate widely as water passes down the soil stack and consequently the water surface in traps moves rapidly up and down. The fluctuations may be so rapid at times that the column of water in the trap is broken and churned around even though it may not be thrown from the trap.

127. Parts of a Drainage System.—The principal parts of the drainage system, which can be called its elements, are the drainage pipes, the traps, and the vent pipes. A soil pipe is any drainage pipe which carries human excrement. If the pipe is vertical it is called a "soil stack." If it is horizontal, or approximately horizontal it is called a "soil branch." A waste pipe carries waste water which does not include human excrement. A vertical waste pipe is called a waste stack and horizontal waste pipes are called waste branches.

The traps* are fittings which hold water in them to prevent the passage of air from the drainage system into the building. The difficulty of maintaining a water seal in a trap is the cause of expense and complication in the installation of plumbing. The invention of a trap which will permit the free and smooth passage of water and solid matter through it and in which the seal cannot be broken would revolutionize plumbing design. Too much emphasis cannot be placed on the importance of providing proper traps and in installing them properly.

* For definition see p. 440.

The vent pipes are attached to the drainage pipes near to the traps and between the trap and the sewer for the purpose of admitting air to or taking air away from the drainage pipes. The vent pipes should lead to the outside air at some distance from any other opening into the building. The ventilation of the drainage pipes at points near to the traps assists in preventing the breaking of the seal in traps by air pressures in the drainage pipes. Under present methods of installing plumbing it would not be possible to maintain the seal in all traps without vent pipes. They are, therefore, of much importance. Their design and the methods of connecting and arranging them is sometimes complicated and will require study.

128. The Fixture Unit.—In the design of the capacity or the size of drainage and vent pipes it is convenient to express the amount of water or drainage to be carried by them in terms of "fixture units." The fixture unit is based upon the rate of discharge from various types of fixtures and has been set as equal to the discharge of 7.5 gal. per minute, or discharges at that rate. This is approximately the rate of discharge from one lavatory.

Table 55 expresses the number of units equivalent to the discharges from the various fixtures listed:

TABLE 55.—FIXTURE UNITS

Fixture	Units	Fixture	Units
One lavatory or wash basin	1	One combination fixture	3
One kitchen sink	1½	One shower bath	3
One bathtub	2	One floor drain	3
One laundry tray	3	One slop sink	4
One urinal	3	One water closet	6

One hundred and eighty square feet of roof or drainage area is equivalent to one fixture unit. In order to determine the number of fixture units equivalent to any fixture not included in the above table the maximum rate of discharge from each fixture, expressed in gallons per minute, should be divided by 7.5.

129. Capacity of Drainage Pipes. *Sloping Pipes.*—The rate at which water will flow through a sloping pipe under what is known as uniform steady flow is well known. It is shown in Table 56 for some common pipe sizes and some common slopes. By uniform, steady flow is meant a condition in which the same quantity of water is continuously passing every section of the channel at the

same time and with the same velocity. Unfortunately this condition does not commonly exist in plumbing pipes because of the frequent obstructions, changes in slope, and additions of water from tributary pipes and fixtures. Any modification of uniform,

TABLE 56.—RATE OF FLOW THROUGH VITRIFIED CLAY AND CAST-IRON PIPE FLOWING FULL[1]
(Gallons per minute)

Diameter of pipe, inches	Slope in inches per foot and per cent														
	Cast-iron pipe								Vitrified-clay pipe						
	1/16 in. 0.5 per cent	1/8 in. 1.0 per cent	3/16 in. 1.5 per cent	1/4 in. 2.0 per cent	5/16 in. 2.5 per cent	3/8 in. 3.0 per cent	1/2 in. 4.0 per cent	Diameter of pipe, inches	1/16 in. 0.5 per cent	1/8 in. 1.0 per cent	3/16 in. 1.5 per cent	1/4 in. 2.0 per cent	5/16 in. 2.5 per cent	3/8 in. 3.0 per cent	1/2 in. 4.0 per cent
2	8.5	12	15	17	19	21	24	4	60	85	104	120	134	147	170
3	25	35	43	50	55	61	70	6	181	257	315	364	406	445	514
4	52	74	91	105	117	128	148	8	380	540	660	760	850	940	1,080
6	160	225	276	318	356	390	450	10	690	980	1,200	1,390	1,550	1,700	1,960
8	330	470	575	665	740	815	940	12	1,150	1,620	1,980	2,300	2,560	2,810	3,240
10	608	860	1,050	1,220	1,360	1,490	1,720								
12	1,000	1,420	1,740	2,010	2,250	2,460	2,840								

[1] For velocities of flow when full, see Table 23.

steady flow conditions will require energy which, in its production at the expense of head, will detract from the capacity of the pipe below that shown in Table 56. Another factor materially affecting the capacity of a pipe is the manner in which the water enters it. If the water enters at a high velocity and in a direction making a small angle with the direction of flow the capacity of the pipe may be increased. If, however, the velocity of the entering water is less than that in the main pipe, or the water enters at right angles, or nearly so, or in the opposite direction, or nearly so, to the direction of flow in the main pipe, the water in the latter will be backed up and the capacity of the pipe will be diminished.

The capacity of pipes in plumbing systems must be expressed in terms of the number and types of connections, turns, etc., as well as in terms of the size, material, and slope. No general expression for capacities can be made in algebraic form. A recommendation alone can be made which is based partially on the results of tests and which will give capacities which are safe to use in conservative

design. Results of tests on the capacity of soil stacks are tabulated below. It is to be understood that these recommendations do not represent the maximum amount of water which can be put through a pipe; they refer only to the capacities for which certain sized pipes should be used under certain specified conditions. Recommendations for the minimum sizes of branch waste and branch soil pipes and the individual waste or soil

TESTS ON CAPACITIES OF SOIL OR WASTE STACKS. CAPACITY IN G.P.M. FOR 10 SEC.

Diameter of stack inches	U. S. Bureau of Standards (*Hoover Report*)		University of Illinois (*Bull.* 143)
	Single or double sanitary T, fittings	Single or double Y, combination Y, and eighteenth bend	Single sanitary T fitting
2	45	90	25
3	100	200	50
4	180	360	100

TABLE 57.—SIZES OF TRAPS AND BRANCH WASTE PIPES FOR ONE FIXTURE ONLY

Kind of fixture	Size in inches	
	Trap	Branch
Lavatory or wash basin	1¼	1¼
Kitchen sinks (small for dwellings)	1½	1½
Kitchen sinks (large for hotels) or restaurant grease trap	...	2
Bathtub	...	1½
Laundry trays (up to five)	2	2
Combination fixtures (sink and tray)	1½	2
Urinal	2	2
Pedestral urinal	2	2
Shower bath (single)	1½	1½
Floor drain or wash	2	2
Yard drain or catch basin	3	3
Slop sink, ordinary	2	2
Water-closet	3	3

branches to fixtures are shown in Tables 57 and 58. Sizes of sewers and house drains are discussed in Sec. 190, page 232.

TABLE 58.—SIZES OF WASTES FOR MORE THAN ONE FIXTURE

Number of units	Slope in inches per foot		
	1/8	1/4	1/2
1	$1\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{4}$
2 to 3	$2\frac{1}{2}$	2	2
4 to 6	3	$2\frac{1}{2}$	$2\frac{1}{2}$
7 to 18	4	4	3
19 to 42	6	6	4
43 to 72	6	6	6
73 to 150	12	10	6

For slopes of 45 deg. or greater the sizes are to be the same as for soil or waste stacks.

130. Capacities of Stacks. *Vertical Pipes.*—Water falling in vertical pipes does not always touch the walls of the pipe in its fall. In leaving the sides of the pipe air is mixed with the falling water and carried along with it. In this manner air currents are created so that the conditions of flow are markedly different than in a slightly sloping pipe. The water falling in a vertical pipe creates a vacuum or suction which might be considered to *increase* the capacity of the pipe; an anomalous condition is created in which it would seem that the more water there is put into a stack the more can be put into it without creating a back pressure. It can be demonstrated that this condition does exist up to the limit when the loss of head due to friction in any distance that the water may fall is equal to this distance. Such a condition might be expected in a 4-in. stack when the velocity approaches 40 ft. per second. The Hoover Report* expresses this velocity, on the assumption that the frictional resistance varies as the square of the velocity, as follows:

$$V = \sqrt{\frac{g}{k} - \frac{\frac{g}{k} - V_0^2}{e^{2ks}}}$$

in which

V = the velocity of flow in the stack.

V = the vertical component of the entrance velocity.

g = the acceleration due to gravity

* Page 106.

e = the base of the Naperian system of logarithms.
s = the height of fall in the stack.
k = a constant depending on the resistance to flow.

It is not possible to use this formula practically because of the lack of knowledge of values of k. The Committee did make measurements of the actual velocities and observations of related phenomena. They conclude:

1. That water falling in vertical stacks reaches an approximate maximum in a comparatively short fall.
2. That in a given stack the maximum (velocity) increases with increased volume of flow.
3. That in a given stack the approximate maximum is attained in a shorter fall with lower volumes of flow.
4. That with volumes of flow proportional to the areas of the cross-sections—*i.e.* proportional to the practical capacities—the maximum (velocity) is smaller and is attained in a shorter fall in the smaller of the two stacks.
5. That with equal volumes of flow the maximum (velocity) is greater and a greater fall is required to attain the maximum in the smaller of the two stacks . . . The only apparent application of this data is on the point of limitation of height of stack of given diameter. For example, if a 3-in. stack in which a height to the highest group of fixtures of 20 ft. is permitted, there is slight reason, on the grounds of increased velocity, for placing any limitation on the height allowed. The velocity attained in a fall of 20 ft. in a 3-in. stack open at both ends is 29 ft. per second. That attained in a fall of 100 ft. will be 34.2 ft. per second.

Even these velocities will be reduced by the retarding action of air resistance.

The capacity of a vertical pipe or stack is dependent on the capacities of the entrances to the stack to pass water into it. In practice it is safe to consider that any vertical stack can carry all of the water which can be put into it by any number of openings which may be expected in a well-designed plumbing layout. The capacity of the stack is, therefore, stated in terms of the style of the connections made to it. Tests have been made on stack capacities under similar conditions at the Bureau of Standards and at the University of Illinois. The results of these tests are embodied in Tables 59 and the table in Sec. 129. The discrepancies in the results shown in this latter table probably due to the bases of the interpretation of the observations.

TABLE 59.—REQUIRED SIZES OF SOIL AND WASTE STACKS

Waste stacks			Soil and waste stacks		
Number of fixture units	Stack, inches	Maximum vertical distance in feet, above the lowest connected fixture	Number of fixture units	Stack, inches	Maximum vertical distance in feet, above the lowest connected fixture
1	1¼	45	37 to 72	3	75
2 to 8	1½	50	73 to 300	4	100
9 to 18	2	55	301 to 720	5	150
19 to 36	2½	60	721 to 1080	6	200
			1081 to 1920	8	300

Note: No water closet should discharge into a stack less than 3 in. in diameter. Not more than three water closets or their equivalent in fixture units should discharge into a 3-in. stack from one 3-in. branch, and not more than two such branches should connect to a 3-in. stack at the same point or level. In no case should the soil or waste pipe or stack be smaller than is required for the branch waste pipes called for in Tables 57 and 58.

The Hoover Report states: "The capacity of a stack should be determined by the capacity of the inlet fitting" but no explanation is given as to what is considered the capacity of an inlet fitting. The Illinois report states:

The rate at which one horizontal waste pipe of the same diameter as the soil stack will discharge water into the soil stack through a sanitary tee without backing up in the waste pipe may be taken to be as follows: 2-in. soil stack, 25 gal. per minute for 7 sec.; 3-in. soil stack, 50 gal. per minute for 7 sec.; and 4-in. soil stack, 100 gal. per minute for 7 sec. These rates are not the greatest rates at which water can enter or flow down a soil stack. The maximum rate at which water will enter a soil stack freely from one horizontal waste pipe is fixed by the type of the connection admitting water to the stack and by the velocity of approach.

Water can be made to enter a soil stack at a higher rate by allowing the pressure to increase in tributary horizontal waste pipes, by using more than one waste pipe at the same or different levels, by using special types of fittings to connect horizontal waste pipes with the soil stack, and in other ways . . . The indications are that the maximum rate at which water will flow down a soil stack is high and that a 4-in. soil stack will take all of the water that would be delivered to it in a five-story building; that a 3-in. soil stack would take all of the water that would be delivered to it in a three-story building; and that a 2-in. pipe is unsuitable for use as a soil stack.

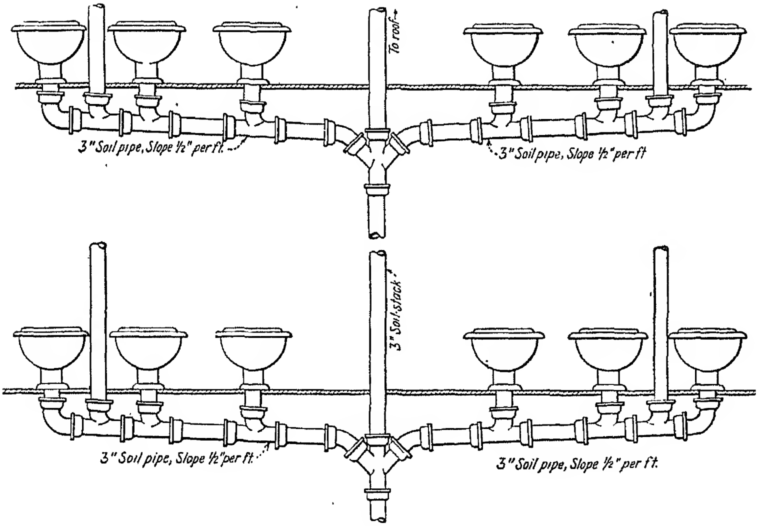


FIG. 94.—Loop venting.

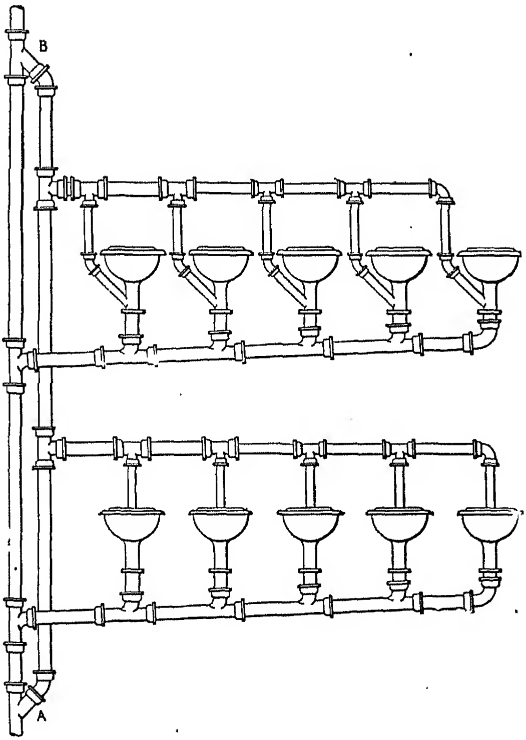


FIG. 95.—Continuous venting.

131. Vents.—The two principal acceptable methods of venting ımbing systems are the continuous vent and the loop vent. ıese are defined in Appendix II. Loop venting is illustrated Fig. 94 and continuous venting in Fig. 95.

A continuous vent to a single fixture is illustrated in Fig. 96 d a system of continuous venting in Fig. 112. Conıuous venting is probably the most satisfactory method of

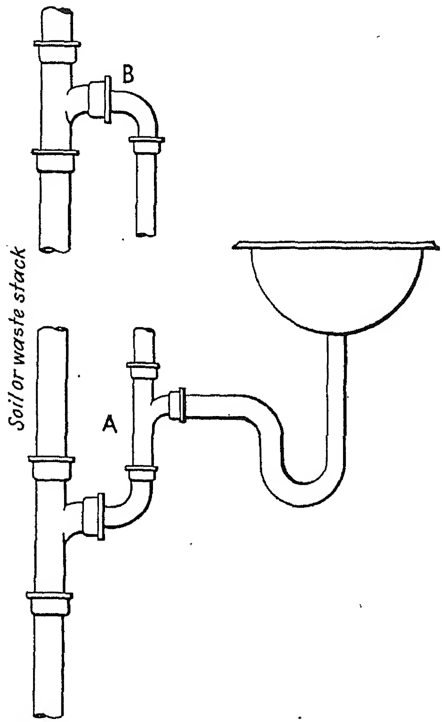


FIG. 96.—Back vent and continuous vent.

talling vents as it is equally effective against siphonage and f-siphonage, or against siphonage or back pressure caused by charges down the stack or by discharges through the same ınch pipe.

\ loop vent for a single fixture is unusual, the method of ıting being particularly applicable to a battery of fixtures. system of loop venting for a number of fixtures is shown in ;. 110. It is to be noted that the last or highest fixture in s figure is practically continuously vented because of the

advantage of continuous over loop venting for a single fixture. Loop venting is useful in special conditions where batteries of fixtures are used and it is not desirable to vent each fixture individually as, for example, in a battery of water closets. Loop venting is useful against self-siphonage, and against siphonage or back pressure caused by discharges down the stack. It may be entirely useless against siphonage or back pressure caused by discharges into the same branch pipe. It is, therefore, restricted to special and appropriate conditions.

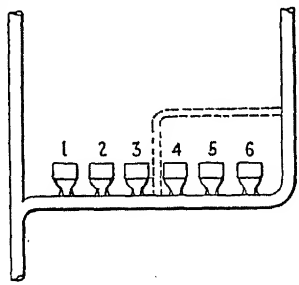


FIG. 97.—Loop venting.

Loop venting under the conditions illustrated in full lines alone (Fig. 97) is undesirable because if fixtures 4, 5, and 6 are discharged simultaneously there is no vent for fixtures 1, 2, and 3 and their seals may be broken by the siphonage created. If fixtures 3, 4, and 6 are discharged simultaneously the seal of the trap on fixture 5 will be blown by back pressure. These difficulties can be overcome by the installation of a vent as shown in dotted lines in the figure.

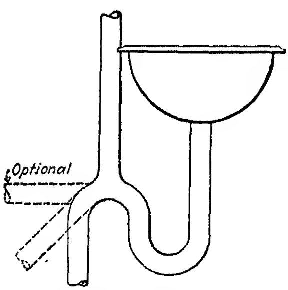


FIG. 98.—Crown vent.

Both continuous and loop venting have their proper uses but continuous venting is of more general use. From comparative tests of continuous and loop venting made at the University of Illinois it has been concluded that:[1]

> . . . continuous venting is the best method to safeguard the seal of traps against breaking due to pressures created by the discharge of fixtures on the same horizontal waste pipe. Loop venting, under such conditions, is valueless. Continuous or crown venting and loop venting are equally effective in relieving the pressures created in traps by water falling down the soil stacks.

Definitions of many kinds and types of vents are given in Appendix II. These definitions include such terms as back vent, unit vent, crown vent, by-pass vent, wet vent, etc.

A crown vent, as shown in Fig. 98, is defined on page 433. The crown vent differs only slightly from the continuous vent shown in Fig. 96 in the position of the connection between the vent pipe

and the waste or soil pipe. Because of its closer proximity to the seal of the trap it might be expected that such a vent would be the most effective but comparative tests of the hydraulic and pneumatic efficiencies have shown no practical advantage of either type of crown or continuous vent over the other. Crown vents have, however, been prohibited by many plumbing codes because experience has shown that grease, hair, or other clogging materials are splashed up into the vent pipe to accumulate there and finally to close the vent.

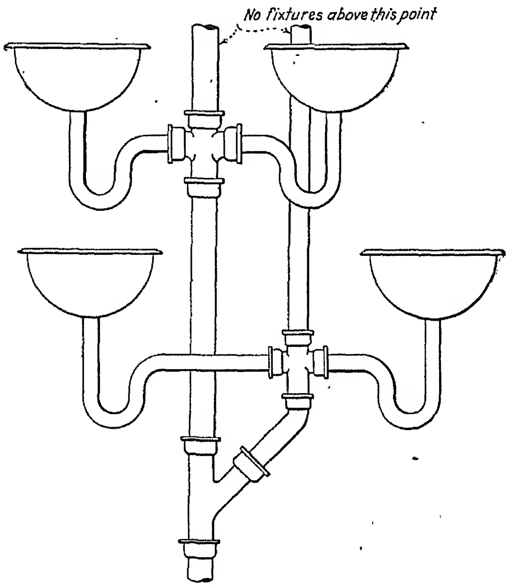


FIG. 99.—Unit vents.

A back vent, or revent, as shown in Fig. 96, is defined on page 432. It is probably the most common method of connecting up vent pipes, particularly for individual fixtures in dwellings. It is generally of the continuous type.

A unit vent, as shown in Fig. 99, is defined on page 441. Its convenience and economy are evident from the figure and it should be used wherever possible.

A wet vent is illustrated at C' on the top floor in Fig. 111. It is defined on page 441. The use of a wet vent is considered as not always desirable because of the danger of clogging the pipe when

the vent is used as a waste or soil pipe thus preventing its use at the same time as a vent pipe. A wet vent may be used as a vent for one fixture only and this fixture should be one which it is probable will not be used at the same time as the fixture

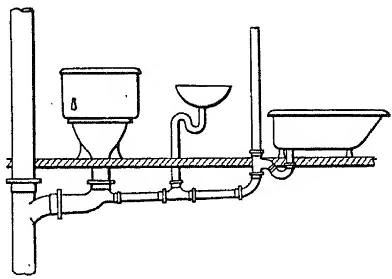


Fig. 100.—Wrong way to install a wet vent.

whose waste pipe is used as a vent. Such an installation as is shown in Fig. 100 should be prohibited as the lavatory trap would siphon itself if both the lavatory and the bathtub were discharged simultaneously. With the reverse condition, as shown on the top floor in Fig. 111, even though the bathtub seal might be broken momentarily by self-siphonage, it would be immediately resealed by water dripping from the tub and during the period that the seal is broken air would be flowing into the plumbing pipes, not out from them.

A by-pass vent is illustrated in Fig. 101. It is a vent pipe parallel to a stack with frequent connections to the stack. The term "by-pass vent" was coined in connection with the tests at the University of Illinois.[2] The effect of such a vent on a tall stack is remarkable. Because of its connection between various parts of a stack regions of high pressure are quickly transferred to regions of low pressure with consequent neutralization of both. Table 60 gives results of tests of by-pass venting and shows the remarkable reductions of pressures therefrom.

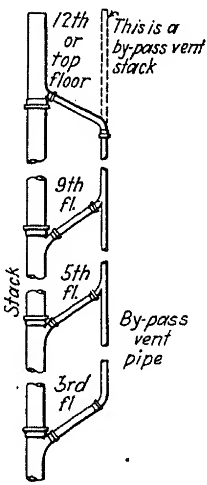


Fig. 101.—By-pass vent and by-pass vent stack.

132. Traps Protected by Vents.—Every trap should be independently protected against siphonage and back pressure, and

TABLE 60.—REDUCTION OF AIR PRESSURE IN A PLUMBING SYSTEM BY VENTING THE SOIL STACK[1]

(Results of tests at Eng. Experiment Station, University of Illinois)

	Pressure in inches of water column				Pressures related to unvented stack as unity			
	Basement	First floor	Second floor	Third floor	Basement	First floor	Second floor	Third floor
4-in. stack without vent	21.9	15.1	13.7	18.1	1.00	1.00	1.00	1.00
4-in. stack with 2-in. by-pass vent	15.8	8.5	10.1	10.9	0.72	0.59	0.74	0.60
4-in. stack with 3-in. by-pass vent	12.7	6.4	10.0	8.7	0.58	0.42	0.73	0.50
4-in. stack with 3-in. by-pass vent stack	16.1	5.0	5.9	3.3	0.74	0.33	0.43	0.18

[1] *Illinois Master Plumber*, p. 16, March 1916.

Average rate of discharge 150 g.p.m. for 7-sec. period, or about the equivalent of three water closets, discharging simultaneously. Basement and first-floor pressures are back pressure: second and third floors are vacuum.

air circulation should be secured, by means of a vent. Crown venting is undesirable because of the dangers of clogging at the crown of the trap. Unit venting is permissible and is to be considered as independent venting.

Loop or circuit vents should be used only when the horizontal waste or soil pipe has a slope of not less than ¼ in. per foot towards the waste or soil stack and the number of fixture units discharged into the horizontal waste or soil pipe is not greater than the number shown in Table 61.

TABLE 61.—CONDITIONS UNDER WHICH LOOP OR CIRCUIT VENTING IS PERMISSIBLE

Diameter of horizontal waste or soil pipe, inches	Maximum number of fixture units when loop venting is used	Diameter of horizontal waste or soil pipe, inches	Maximum number of fixture units when loop venting is used
1½	2	5	30
2	3	6	72
3	9	8	210
4	18	10	500

The circuit or loop vent should be taken off the horizontal soil or waste pipe immediately below the last fixture connection, except where the last fixture is connected to a vertical portion of the soil or waste pipe as shown at *A* in Fig. 110.

Where fixtures discharge into a soil or waste stack above its connection with a horizontal soil or waste pipe, to which more than one fixture is connected, and which is used as a circuit or loop vent, the horizontal soil or waste pipe which is used as a circuit or loop vent should be provided with a relief vent taken off between the soil or waste stack and the nearest fixture connection, as shown at *B* in Fig. 110.

Where loop or circuit vents are used on different floors and such vents connect into the same vent stack the connection between the branch vent, on all but the lowest floor, and the vent stack shall be made at a point above the fixtures, on each floor, as shown at *B* in Fig. 110.

133. Distance of Vent from Trap Seal.—Every trap should be placed as near as possible to its vent and no trap should be placed more than 5 ft., horizontal developed length, from its vent, except (1) the distance between a vent and trap may be 5 ft. or more if all of the six conditions stated in Sec. 134B are fulfilled, and (2) except that the distance between a vent and trap may be 15 ft. or less on the waste from a surgical operating table or similar fixture. The distance should be measured along the central line of the waste or soil pipe from the vertical inlet of the trap to the vent opening. The vent opening from the soil or waste pipe, except from water closets or similar fixtures, should not be below the crown weir of the trap.

134. Permissible Installation of Unvented Trap.—Among the results of the tests conducted at the University of Illinois and at the U. S. Bureau of Standards it has been demonstrated that under certain circumstances it is safe to install traps without vents. These circumstances are described in the following paragraphs:

A. Drum traps or other non-siphon traps may be used without vents on fixtures having an approximately flat area of not less than 50 sq. in. at the bottom thereof adjacent to the outlet, provided, however: first, that the waste from the fixture is connected to a soil or waste stack in which the distance that water falls above the connection is not greater than that shown in Table 62 (see Fig. 102), or second that there is at least one vented

fixture attached to the same branch waste as the fixture on which the non-siphon trap is used, and that the vent pipe on the vented fixture is not less than the size called for in Tables 63 to 68, inclusive (see *W*, in Fig. 113).

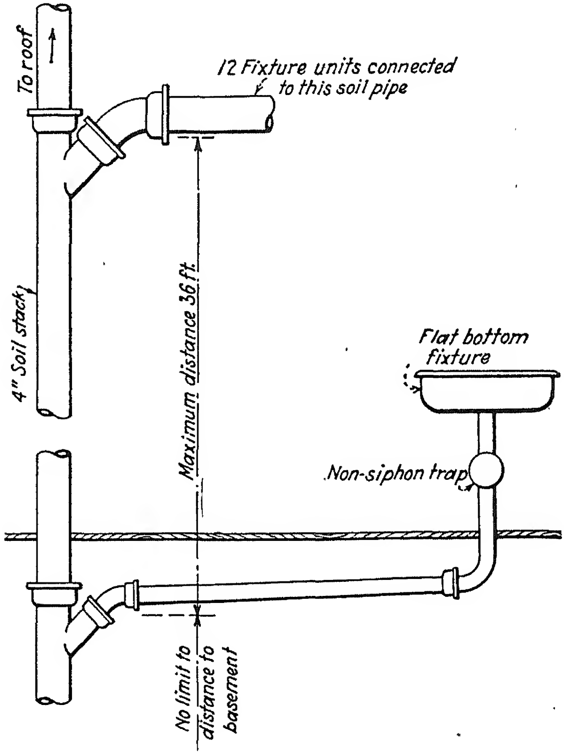


FIG. 102.—Illustrating the table in exception *A* of Sec. 136.

B. A vent is *not* required on the trap on a fixture in which all of the following six conditions are fulfilled:

Condition No. 1.—(*a*) The unvented trap shall discharge directly into a soil or waste stack through a waste or soil branch to which no other fixture is connected, as illustrated at *D*, *E*, and *F*, in Fig. 111 or, (*b*) the trap shall discharge into a horizontal pipe to which any connected fixture in the direction away from the stack, is vented in accordance with the conditions outlined in Sec. 135 (see *A* and *B* in Fig. 111).

Condition No. 2.—The number of fixture units connected to the stack at or above the level of the unvented fixtures, is not

TABLE 62.—MAXIMUM DISTANCE IN FEET THROUGH WHICH WATER MAY FALL IN A VERTICAL PIPE TO A HORIZONTAL BRANCH PIPE ON WHICH NO VENTED FIXTURES ARE CONNECTED

(The distance is to be measured in the vertical pipe above the connection of the horizontal branch to the vertical pipe. Distances are measured in feet)

Number of fixture units discharging into the stack above the non-siphon trap	Diameter of soil or waste stack, inches					
	2	3	4	5	6	8
6	24	40	50	64	80	112
12	18	28	36	48	60	84
24	12	19	30	40	50	70
48	10	16	29	36	47	66
96	..	14	26	35	44	60
192	..	12	24	32	40	58
384	..	..	23	30	38	52

greater than 18 of which no more than 12 such units are on the same floor. Only one water closet is connected to a 3-in. stack and not more than two water closets are connected to a 4-in. stack above the level of the unvented fixture. This condition is illustrated in Fig. 111 and at M and at N in Fig. 113.

Condition No. 3.—The distance that any water may fall in the stack to the lowest connected fixture is not greater than 20 ft. This condition is illustrated in Fig. 111 and in Fig. 113.

Condition No. 4.—(*a*) The water seal in the unvented trap is automatically restored after each use of the fixture, as in a water closet, as shown at A in Fig. 111; or (*b*) there is at least 50 sq. in. of approximately flat area in the bottom of the fixture adjacent to the outlet, as shown at B, E, and F, in Fig. 111, or; (*c*) the waste pipe from the fixture is on a slope of not less than ⅛ nor greater than ¼ in. per foot, is not more than 2 ft. in length, and is connected to a soil or waste stack or horizontal pipe of not less than 3 in. in diameter at a point not less than 2 in. above the dip of the trap.

Condition No. 5.—The stack into which the fixtures discharge shall not be less than 3 in. in diameter and the length of the waste or soil branch from any fixture to the soil stack or to a

horizontal soil or waste pipe on which there is a fixture vented in accordance with the conditions outlined in Sec. 135, shall not be greater than 4 ft.

Condition No. 6.—The connection between the vertical stack and the house drain or other horizontal turn shall be made with a long-sweep fitting of radius of not less than three diameters.

C. A vent is not required on the trap on a fixture where not more than eight separate fixtures of one unit, or less, each, are connected to a 3-in. or larger, waste stack or not more than twelve separate fixtures of one unit or less, each, are connected to a 4-in., or larger, waste stack, in which the distance that any water may fall in the stack to the lowest unvented fixture is not greater than 45 ft., provided in addition, that conditions 1, 4, 5, and 6 above are fulfilled (see *E* in Fig. 113).

D. Where bathrooms or water closets or other fixtures are located on opposite sides of a wall or partition or directly adjacent to each other within the prescribed distance, such fixtures may have a common soil or waste pipe and a common vent, as illustrated in Fig. 99.

135. Sizes of Vents.—Rules for the determination of the sizes of vent pipes are difficult to formulate because of the variety and number of the factors involved. In most of those plumbing codes in which sizes of vent pipes are specified, this difficulty is overcome by fixing arbitrary sizes for specific conditions. Although not necessarily the smallest sizes that will serve for the conditions they give convenient sizes that are supposedly sufficiently large to control any pressure which is likely to develop.

Tests to determine adequate vent sizes have been conducted at the U. S. Bureau of Standards and at the University of Illinois. The recommendations resulting from the Bureau of Standards tests are given on pages 35, 120, and 122, of the Hoover Report. The recommendations resulting from the tests at the University of Illinois are published in *Bulletin* 143 of the Engineering Experiment Station. These recommendations have been modified and extended in form and have been published by the Illinois State Department of Public Health in the Illinois Model Plumbing Code. These recommendations are more extensive than those of the Bureau of Standards and fit more varied conditions. They are as follows:

The minimum size of branch and main vent pipes and vent stacks are given in Tables 63 to 68, inclusive, with the following exceptions:

TABLE 63.—MINIMUM SIZES OF VENT PIPES IN INCHES TO CONNECT TO 1½-, 2-, AND 2½-IN. WASTE PIPES

Diameter of waste, inches	Height[1] of waste, feet	Length of vent, feet	Number of fixture units permitted to discharge into the waste stack above the waste pipe which is served by the vent, the size of which is given in this table			
			1	2 to 8	9 to 18	19 to 36
1½	30	20	1¼	1¼	1¼	1¼
		30	1¼	1¼	1¼	1½
	40	20	1¼	1¼	1¼	1¼
		30	1¼	1¼	1½	1½
		40	1¼	1½	1½	1½
2	30	15	1¼	1¼	1¼	1¼
		20	1¼	1¼	1¼	1½
		30	1¼	1¼	1½	1½
	40	10	1¼	1¼	1¼	1¼
		20	1¼	1¼	1½	1½
		30	1¼	1¼	1½	2
		40	1½	1½	2	2
	50	10	1¼	1¼	1½	1½
		20	1¼	1½	1½	1½
		35	1¼	1½	1½	2
		50	1½	1½	2	2
2½	20	20	1¼	1¼	1¼	1¼
		20	1¼	1¼	1¼	1½
	25	20	1¼	1¼	1¼	1½
		25	1¼	1¼	1½	1½
	30	20	1¼	1¼	1¼	1½
		30	1¼	1¼	1½	1½
	40	20	1¼	1¼	1½	1½
		30	1¼	1½	1½	2
		40	1½	2	2	2
	50	10	1¼	1¼	1½	1½
		20	1¼	1½	1½	1½
		35	1½	1½	2	2
		50	2	2	2½	2½

[1] This is the greatest distance that water falls in the waste stack above the lowest connected fixture.

(a) No vent pipe need be larger in diameter than the soil or waste pipe into which it vents. A vent pipe, smaller in diameter than that called for in the tables, or more than 6 ft. long shall not be longer than twice the developed length of the soil or waste pipe served.

(b) No vent pipe on a trap discharging into a soil pipe or soil stack shall be less than 1½ in. in diameter.

(c) No vent pipe shall be less than 1¼ in. in diameter.

In comparing the sizes of vent pipes as recommended by the two authorities referred to it is found that they are not always in agreement. The accuracy or safety of the use of the smaller-sized pipe allowed by either authority can be determined only by tests, and the results of no such test are available for study. Both authorities have based their recommendations on tests of relatively short stacks and small rates of discharge and have extended the results to higher stacks and larger rates of discharge.

136. Sizes of Branch and Individual Vents.—The length of a branch vent should not exceed the maximum length permitted

TABLE 64.—MINIMUM SIZES OF VENT PIPES IN INCHES TO CONNECT TO 3-IN. SOIL STACKS

Height of soil stack in feet[1]	Length of vent pipe in feet	Number of fixture units permitted to discharge into the stack above the waste or soil pipe which is served by the vent, the size of which is given in this table			
		1 to 18	19 to 42	43 to 72	73 to 150
45	20	1½	1½	1½	2
	30	1½	1½	2	2
	45	1½	2	2	2
60	10	1½	1½	1½	2
	20	1½	1½	2	2
	30	1½	2	2	2½
	45	2	2	2½	2½
	60	2	2½	2½	2½
75	10	1½	1½	2	2
	25	1½	2	2½	2½
	45	2	2½	2½	3
	60	2	2½	3	3
	75	2½	3	3	3

[1] This is the greatest distance that water falls in the soil stack above the lowest connected fixture.

for the main vent serving the same size soil or vent stack nor should the combined length of branch and main vent exceed the permissible lengths given in Tables 63 to 68 inclusive.

137. Vent Pipes. Grades and Connections.—All vent and branch vent pipes should be free from drops or sags and should

TABLE 65.—MINIMUM SIZES OF VENT PIPES IN INCHES TO CONNECT TO 4-IN. SOIL STACKS

Height of soil stack in feet[1]	Length of vent pipe in feet	Number of fixture units permitted to discharge into the stack above the waste or soil pipe which is served by the vent, the size of which is given in this table				
		1 to 18	19 to 42	43 to 72	73 to 150	151 to 300
35	10	1½	1½	1½	1½	2
	20	1½	1½	2	2	2
	30	1½	1½	2	2	2½
50	10	1½	2	2	2	2½
	30	2	2½	2½	2½	3
	50	2½	2½	3	3	3
75	10	2	2½	2½	3	3
	30	2½	3	3	3	3½
	50	3	3	3	3½	3½
100	10	2½	3	3	3½	3½
	30	3	3½	3½	3½	4
	50	3½	3½	3½	4	4
	100	3½	4	4	4	4

[1] This is the greatest distance that water falls in the soil stack above the lowest connected fixture.

be graded and connected so as to drop back to the soil or waste pipe by gravity. All vent lines should be connected at the bottom with a soil or waste pipe in such a manner as to prevent the accumulation of rust, scale, or condensation. Where vent pipes connect to a horizontal soil or waste pipe the vent branch should be taken off above the center line of the pipe, and, where possible, the vent pipe should rise vertically or at an angle of 45 deg. or more from the horizontal to a point at least 6 in. above the fixture it is venting before offsetting horizontally or connecting to the branch, main waste, or soil vent.

Where it is not possible to fulfil the preceding conditions so far as the extension of the vent above the fixture is concerned, and the vent must be laid at an angle less than 45 deg. from the horizontal, a wet vent through which no human excrement will be discharged should be used, or some provision should be made for flushing the vent frequently.

TABLE 66.—MINIMUM SIZES OF VENT PIPES IN INCHES TO CONNECT TO 5-IN. SOIL STACKS

Height of soil stack, feet[1]	Length of vent pipe, feet	Number of fixture units permitted to discharge into the stack above the waste or soil pipe which is served by the vent, the size of which is given in this table						
		1 to 18	19 to 42	43 to 72	73 to 150	151 to 300	301 to 480	481 to 720
30	20	2	2	2	2½	2½	3	3½
	30	2	2½	2½	2½	3	3	3½
45	10	2	2	2½	2½	3	3	3½
	30	2	2½	2½	3	3	3	3½
	45	2½	2½	3	3	3½	3½	4
60	10	2	2½	2½	3	3	3½	3½
	30	2½	2½	3	3	3½	3½	3½
	45	2½	3	3	3½	3½	3½	4
	60	2½	3	3½	3½	3½	3½	4
100	20	2½	3	3	3½	3½	3½	4
	50	2½	3	3½	3½	3½	3½	4
	75	3	3½	3½	3½	3½	4	4
	100	3½	3½	3½	4	4	4	4
150	50	3	3½	3½	3½	4	4	4
	75	3	3½	3½	4	4	4	4
	100	3½	3½	4	4	4	4	5
	150	3½	4	4	4	4	5	5

[1] This is the greatest distance that water falls in the soil stack above the lowest connected fixture.

Where the bottom of a vent stack connects with any other pipe and no provision is made for automatically flushing the bottom portion of the vent stack, the unflushed portion of the vent stack should slope at least 45 deg. from the horizontal. All main vents or vent stacks should connect, full size, at their base to the main soil or waste pipe at or below the lowest fixture branch and should extend undiminished in size above the roof or be reconnected with the main soil or waste stack above the highest fixture, as shown in Figs. 95 and 96.

138. Fresh-air Inlets.—Fresh-air inlets are connections between the house drain and the open air for the purpose of ventilating the plumbing system and to prevent the development of excessive back pressure. They are used primarily in connection with a main or house trap. A fresh-air inlet is shown at numbers 79, 164, and 167 at the front of the first floor, in Fig. 109. Where a main trap is used the fresh-air inlet must be connected to the house drain well above the main trap so as not to interfere with the cleanouts therein. In cold climates the fresh-air inlet should join the house drain at least 15 ft. above the main trap to avoid freezing of the water in the trap. A fresh-air inlet should be used where there is danger of submerging the end of the house drain or sewer. Under these conditions it should be connected to the house drain above the highest point at which it is expected that water may back up. The opening of the upper end of the

TABLE 67.—MINIMUM SIZES OF VENT PIPES IN INCHES TO CONNECT TO 6-IN. SOIL STACKS

Height of soil stack, feet[1]	Length of vent pipe, feet	Number of fixture units permitted to discharge into the stack above the waste or soil pipe which is served by the vent, the size of which is given in this table								
		1 to 18	19 to 42	43 to 72	73 to 150	151 to 300	301 to 480	481 to 720	721 to 840	841 to 1,080
45	30	2½	2½	2½	3	3	3	3½	3½	4
	45	2½	2½	3	3	3	3½	3½	3½	4
60	30	2½	2½	3	3	3	3½	3½	3½	4
	45	2½	3	3	3	3½	3½	4	4	4
	60	3	3	3	3½	3½	4	4	4	5
100	30	2½	3	3	3½	3½	3½	4	4	4
	50	3	3	3½	3½	4	4	4	4	4
	75	3	3½	3½	4	4	4	4	4	5
	100	3½	4	4	4	4	4	5	5	6
150	50	3	3½	4	4	4	4	5	5	5
	75	3½	4	4	4	5	5	5	5	5
	100	4	4	4	5	5	5	5	5	6
	150	4	4	5	5	5	5	5	6	6
200	50	3½	4	4	4	5	5	5	5	6
	100	4	4	4	5	5	5	5	6	6
	150	4	5	5	5	5	6	6	6	6
	200	5	5	5	5	6	6	6	6	6

[1] This is the greatest distance that water falls in the soil stack above the lowest connected fixture.

inlet should be located 12 ft. or more away from any other opening into a building and preferably not under any door or window. The inlet should be protected with a substantial cover which can not be easily removed and which will permit the passage of air into or out of the pipe. It is desirable, where possible, to

TABLE 68.—MINIMUM SIZES OF VENT PIPES IN INCHES TO CONNECT TO 8-IN. SOIL STACKS

Height of soil stack, feet[1]	Length of vent pipe, feet	Number of fixture units permitted to discharge into the stack above the waste or soil pipe which is served by the vent, the size of which is given in this table									
		1 to 18	19 to 42	43 to 72	73 to 150	151 to 300	301 to 480	481 to 720	721 to 840	841 to 1,080	1,081 to 1,800
50	25	3	3	3	3	3½	3½	3½	4	4	4
	50	3	3	3	3½	3½	3½	4	4	5	5
75	30	3½	3½	3½	4	4	4	5	5	5	5
	50	3½	3½	4	4	4	5	5	5	5	5
	75	3½	4	4	5	5	5	5	6	6	6
	100	4	4	5	5	5	5	6	6	6	6
150	50	4	4	5	5	5	5	5	6	6	6
	75	4	4	5	5	5	5	6	6	6	6
	100	4	5	5	5	6	6	6	6	8	8
	150	5	5	6	6	6	6	6	6	8	8
200	50	4	5	5	5	5	6	6	6	6	6
	100	4	5	5	5	6	6	6	6	6	6
	150	5	6	6	6	6	6	6	8	8	8
	200	5	6	6	6	6	6	8	8	8	8
300	50	4	5	5	5	5	6	6	6	6	6
	100	4	5	5	5	6	6	6	6	8	8
	200	5	6	6	6	6	6	6	8	8	8
	300	6	6	6	6	6	6	8	8	8	8

[1] This is the greatest distance that water falls in the soil stack above the lowest connected fixture.

screen the inlet in shrubbery. In closely built-up communities it is necessary to carry the fresh-air inlet up to the roof.

The size of the fresh-air inlet is based on the size of the house drain as shown in Table 69.

TABLE 69.—SIZES OF FRESH-AIR INLETS

Size of house drain, inches............	4 or less	5 or 6	7 or 8	10 or larger
Size of fresh-air inlet, inches..........	Same as house drain	4	6	8

139. Drainage Fittings.—Detailed information concerning the material, dimensions, and types of drainage fittings are given in Chap. XIV, and in Sec. 6 of Appendix I. The use of short radius or right-angle bend fittings is undesirable since they are conducive to clogging and to the development of higher pressures than when long-sweep fittings are used. Long, sweeping curves and smooth, easy channels free from excessive roughness or sudden enlargements or contractions are to be desired in any connection between the pipes in a drainage system. Because of the thin partitions, walls, or floors sometimes used in building construction, short-turn fittings must occasionally be used but their use is to be avoided.

The use of certain types of fittings is sometimes prohibited on account of the difficulties which experience has shown result therefrom. Among the excluded fittings are all saddle fittings on soil pipes; traps with hidden partitions or tortuous passages; double-T fittings on horizontal lines; fittings which provide a lodging place for solids; or any fitting or connection which has an enlargement, chamber, or recess with a ledge, shoulder, or reduction of the pipe area in the direction of the flow on the outlet or drain side of a trap. The use of rubber or putty in making a connection is usually prohibited. The use of drive ferrules is not good practice and combination lead ferrules should be used only when the calked joint can be made in the upright position. A fitting over which there is some controversy is the main or house trap. Some codes require it, others prohibit it, few are silent on the subject.

140. Cleanouts.—An easily accessible cleanout should be provided at the foot of each stack, at least at each alternate change in direction in a main soil or waste pipe, and within the building close to the outside wall through which the house drain passes to join the house sewer. This latter cleanout should be made with a full-sized Y or other full-sized opening. All other cleanouts should be of the same nominal size as the pipes in which they are inserted up to 4 in. and for larger pipes they should not be less than 4 in. The distance between the cleanouts in horizontal pipes is discussed in Sec. 144. It is undesirable to make this distance greater than 50 ft.

The bodies of cleanout ferrules should be made of standard pipe sizes, conforming in thickness to that required for pipe and fittings of the same metal, and extending not less than ¼ in.

above the hub. The cleanout cap or plug should be of heavy, red brass not less than 1/8 in. thick or of cast iron not less than 3/16 in. thick. It should have a flat face or surface to conform to or to rest upon the outer end of the ferrule. The cap or plug should not be screwed into place but should be held in position by a bolt or bolts fastened to the ferrule. The joint should be made tight by the use of a gasket.

All underground traps and cleanouts, except where cleanouts are flush with the floor, and all exterior underground traps should be made accessible by manholes with proper covers. Any floor or wall connection of fixture traps when screwed or bolted to the floor or wall can be used as a cleanout.

141. Refrigerator, Safe, and Special Wastes.—Fixtures containing food should not be connected directly to pipes containing sewage regardless of the fact that traps may be inserted in the drain pipes from such fixtures, because of the great danger present from the possibility of the breaking of the seal between the sewer and the food in the receptacle.

The waste pipes from such fixtures should be trapped and should empty into an open sink that is properly supplied with water, connected, trapped, and vented the same as other fixtures, or the waste pipe may empty into a floor drain, but the end of the waste pipe must be left open. It is undesirable to locate the ends of such waste pipes in inaccessible places or poorly ventilated cellars. A proper installation is illustrated at *U* in Fig. 113.

Refrigerator waste pipes should not be less than 1¼ in. in diameter for one opening, 1½ in. for two openings, and for four to twelve openings it should not be less than 2 in. It should be trapped at each opening and cleanouts should be provided so that the pipe can be flushed. It is desirable to continue such waste pipes through the roof except where the fixtures are located in the basement or on the first floor. This condition is illustrated at *V* in Fig. 113.

Overflow pipes from a water-storage tank, motor exhausts, or other clear-water wastes should discharge through the traps in rain-water leaders, floor drains, or other infrequently used traps. They should not be directedly connected to drainage pipes containing sewage because of the infrequency of their use. It is most desirable to terminate them as provided for refrigerator wastes. The desired condition is illustrated at *X* in Fig. 113.

Floor-drain waste pipes should be trapped and, if possible, not directly connected to a drainage pipe containing sewage unless provision is made for the renewal of the seal in the trap of the floor drain.

142. Exhaust or Blow-off Pipes from Steam Boilers, Etc.—The exhaust, blow off, sediment, or drip pipe from a steam boiler or other machine from which water at a high temperature or containing much sediment is drained should not be directly connected to the ordinary pipes of the plumbing system to which other common fixtures are connected. Such pipes should discharge into the top of and above the level of discharge of a closed tank or condenser made of wrought or cast iron or steel. The tank should be provided with a relief or vent pipe not less than 3 in. in diameter extending to the outer air and not connected to any other pipe.

The depth from the discharge level to the bottom of the tank should not be less than 24 in. The waste pipe from the tank should not be smaller in diameter than the inlet pipe nor less than 3 in. in diameter. It should, when possible, connect to the house sewer or main sewer and not to the house drain. Such waste pipes need not be trapped but they should be properly vented.

References

1. "Hydraulics and Pneumatics of House Plumbing," *Bull.* 143, Eng. Expt. Station, University of Illinois, pp. 62 and 77, 1924.
2. *Illinois Master Plumber*, March, 1926.

CHAPTER X

DRAINAGE AND VENT-PIPE INSTALLATION

143. Drainage-pipe Arrangements.—A piping layout shown on a plan should include a complete presentation of the location of both the supply and the drainage pipes. Roughing-in consists in installing these pipes during the erection of the building before the lathing of the walls or the completion of the floors. The placing of the fixtures is not included as a part of the roughing-in. A designer, to plan a proper layout for a plumbing system, must know how to make the user comfortable, must understand the phenomena occurring in the pipes, and must be acquainted with the practices of plumbing. Comprehensive general rules of value would be difficult of statement because of the multitude of conditions which may arise.

The aim in the layout of a drainage system is to satisfy the comfort and wishes of the user and at the same time to take waste water and suspended solids away rapidly with the least danger from clogging, noise, leakage, and trouble, and with the least expense.

144. Installation of Drainage Pipes.—The drainage pipes of a plumbing system are installed in the walls and between the floors of buildings, in pipe runs, or are otherwise concealed. They should, however, be made as accessible as possible so as to permit of observation and repairs. Vertical pipes should be supported at each floor by collars or iron hangers attached to the walls or floors of the building and caught under a pipe hub. The base of every stack should rest on a masonry pier or a cast-iron pedestal. Sloping pipes are supported within the wall or floor on the floor joists or by such means as are described in Secs. 51 and 145. The house drain, when only slightly above the cellar floor, is supported on masonry or metal pedestals which should not be more than 10 ft. apart.

The movements resulting from the expansion and contraction of cast-iron pipe due to temperature changes differ so little from the movements of other parts of the building from the same cause

that no special provision need be made for them. Allowance must be made, however, for movements of the building from other causes such as settling of the foundation, the wind, etc. The use of non-rigid supports is discussed in Sec. 51.

The placing of branch pipes on a slope of ¼ in. per foot is facilitated by the general use of threaded drainage fittings which are tapped to provide this slope. The permissible distance between traps and vent pipes, the location of cleanouts, and other details are covered in Chap. IX. Restrictions as to the proper installation of plumbing pipes vary between different plumbing codes, for example: a comparison between the codes of nineteen large cities of the United States shows three which require a cleanout every 25 ft.; three at 30 ft. three at 40 ft.; eight at 50 ft.; one at 60 ft.; and one at 100 ft. Practically all codes require a cleanout at the base of a stack and at the outer wall of the building.

145. Drainage-pipe Supports.—All pipes should be supported so that their weights do not bear upon a calked joint, except when the spigot end of one vertical pipe rests in the hub of the next lower vertical pipe. All soil and waste stacks should be thoroughly supported on concrete or masonry piers or should have substantial foot rests at their bases; soil or waste stacks 10 ft. or more in height should also be provided with floor rests or other substantial support at 10-ft. or floor intervals. Brick supporting piers should be at least 18 in. square.

Connections of wall hangers' pipe supports, or fixture settings with masonry, stone, or concrete backing, should be made with the use of expansion bolts without the use of wooden plugs.

Horizontal runs of pipe above the floor should be supported or anchored by wall brackets, iron hangers, or masonry piers at intervals not to exceed 10 ft. for all materials except lead. Lead pipe should be supported for its entire length or at very close intervals.

Various methods for the support of pipes are discussed in Sec. 51. Many of these methods are equally applicable to the support of drainage and vent pipes.

146. Connections between Pipes.—The materials and the methods of using them in the making of certain types of pipe joints are described in Secs. 158 to 166. The following recommendations concern the types of connections to use under certain conditions will serve as a guide to good practice:

Vitrified Clay Pipe.—The joints between vitrified clay pipe or between vitrified clay pipe and metal pipes should be poured joints except the joints in a vitrified clay house sewer or between a house sewer and a house drain. Such joints may be of cement.

Cast-iron Pipe.—Joints in cast-iron pipe should be either calked or screwed joints.

Wrought-iron, Steel, Brass, or Copper Pipes.—Joints in such pipes should be threaded and should be made with couplings, unions with gasket or ground face, or an extra heavy running thread with lock nut made tight with wicking and red or white lead.

Wrought-iron, Steel, Brass, or Copper to Cast-iron.—Such joints should be either threaded or calked.

Slip Joints and Unions.—These should be used only on the inlet side of a trap or on flush pipes from tanks.

Roof Joints.—These should be made tight by the use of copper or lead plates or flashing.

147. Grades and Alignment of Drainage and Vent Pipes.—Drainage and vent pipes should be installed in as direct and straight an alignment as possible. When offsets or changes in direction are necessary they should be made, where possible, at an angle of not less than 45 deg. Quarter bends and sanitary types of fittings should be used only to change from the horizontal to the vertical direction. All other changes in direction should be made by the use of appropriate "eighth" or "sixteenth" bends, Ys, half-Ys, Y-and 1/8 bends, or similar type of fitting or connection in which the change of direction is gradual. Where changes in size of pipe are necessary they should be made with reducing or increasing fittings. These fittings should be pitched at an angle of not more than 45 deg. with the center line of the pipe between the two sizes.

Waste and soil pipes should not decrease in diameter in the direction of flow of water and vent pipes should not decrease in diameter in the direction from a waste or soil pipe to their connection or opening into the free air.

Piping should never be laid horizontal. So-called horizontal pipe should be laid at a uniform grade, preferably about 1/4 in. per foot, and under no conditions at a grade of less than 1/8 in. per foot. Other requirements with regard to the grades and connections of vent pipes are stated in Chap. IX.

148. Offsets in Stacks.*

Many questions have been asked concerning offsets in soil or waste stacks. We may answer these questions as far as the data at hand and theoretical considerations justify conclusions. If the offset is above the highest fixture connection to the stack, there can be but slight effect on the functioning of the system. If the offset is below the lowest point of fixture connections to the stack, the effect will be similar to that from a house drain at the same level as the offset. The longer the offset the more nearly will the effects approach those of a house drain at the same level. The farther the offset is placed below the lowest fixture connection the more nearly the effect will approach that of the straight stack. The effect of offsets in the stack between levels of fixture connections to the stack is problematical and will doubtless be found to vary with different installations. This last is a condition of construction which should be avoided when possible, and which, if impossible to avoid, should be safeguarded by additional vent connections to the stack at the fixture levels on either side of the offset.

149. Connections between Branch Pipes and Stacks.—In Sec. 130, it is pointed out that the capacity of a stack, like the capacity of a sloping pipe, is dependent on the capacity of the entrances to the stack to pass water into it. The capacity of the connecting fittings, therefore, limit the capacities of the drainage pipes.

In testing the capacities of drainage fittings at the University of Illinois, they have been set up in the positions used in practice and water has been discharged into them continuously at various rates until a rate was reached above which the height of water in a glass tube connected to the inlet opening indicated that the inlet opening was flowing full. Any increase in the rate of flow would cause water to back up in the branch pipe. One apparatus used was similar to that shown in Fig. 123 and another apparatus was similarly arranged so that all vent pipes and Ts were replaced by straight pipes with total lengths of 10 ft. on each floor. The total fall was about 20 ft. with 10 ft. between floors. Water entered the end of the horizontal pipes furthest from the stack. The capacity of the fitting is reported as the rate of flow which would just fill the entrance to the fitting with no length of discharge pipe below the fitting and the water entering the fitting as indicated. In practice, water can be passed more rapidly through a fitting because of the velocity of approach

* From Hoover Report, p. 127.

and siphonage created in long vertical drops. The capacities of the fittings determine the assumptions to be made with regard to drainage-pipe capacities in the design of plumbing systems.

150. Soil- and Waste-pipe Connections.—All soil and waste stacks should be provided with correctly faced inlets for fixture connections. Connections to soil and waste stacks should be made with sanitary T and Y fittings or 45-deg. fittings or as explained in Sec. 147. No double-hub, double-T, or double-sanitary-T branch should be used on horizontal soil or waste lines.

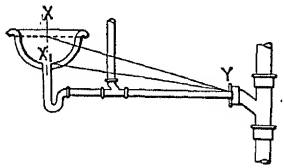
151. Connections at Base of Stacks.—The pressures in a plumbing system are affected materially by the type of connection, or foot piece between the stack and the house drain or other sloping pipe into which the stack may discharge. Tests[1] made in the Eng. Experiment Station at the University of Illinois show that the back pressure may be varied between zero, when the stack is allowed to discharge wide open without obstruction, up to the highest amounts when a short-turn 90-deg. ell of the same diameter as the stack is used. It is probable that higher pressures

TABLE 70.—PRESSURES CREATED IN A 4-IN. SOIL STACK BY THE DISCHARGE OF WATER THROUGH IT, USING VARIOUS TYPES OF BASE FITTINGS
(The pressures are measured on unvented traps placed at various elevations along the stack. Positive or back pressures are indicated by +. Negative pressures or siphonage are indicated by −)
(*From tests made in the Eng. Experiment Station, University of Illinois*)

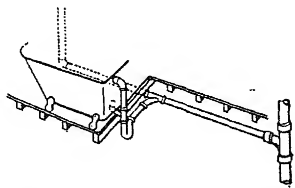
Type of base fitting	Pressures in inches of water at the following number of feet above the base fitting			
	2	6	22	35
Soil stack discharging vertically downwards on to the floor, without base fitting	− 1.91	....	....	−20.10
Long sweep 90-deg. ell with radius of 12 in.	+ 5.34	+ 3.85	−13.24	−13.29
Medium sweep 90-deg. ell with radius of 5 in.	+ 9.46	+ 6.72	−11.40	−12.77
Two 45-deg. ells with an 11-in. length of nipple between them	+11.20	+ 7.02	−10.58	−13.73
Short sweep 90 deg. ell with radius of 4 in.	+15.00	+ 9.30	−12.60	−15.08
Low heel outlet 90 deg. ell with radius of bend of 3 in. Heel outlet is closed	+19.30	+13.20	−12.14	−15.38

could be obtained if a fitting of smaller diameter than the stack were used, but such a connection would be impracticable.

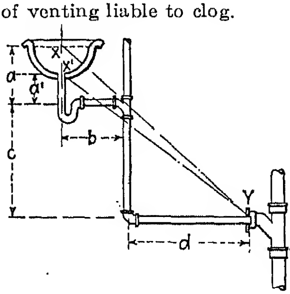
The tests were made by installing various types of base connections on the base of a 4-in. stack 42 ft. long. Water was discharged into the top of the stack at various rates and pressures at different



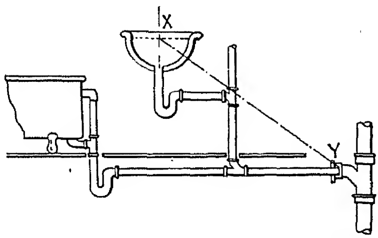
Type of venting liable to clog.



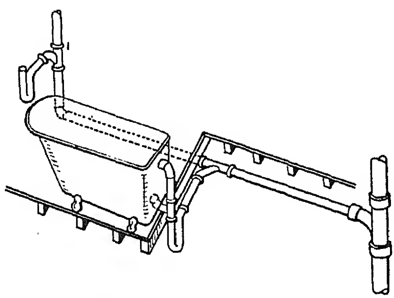
Type of venting liable to clog.



Type of venting least liable to clog.



Type of venting protected from clogging.



Type of venting not liable to clog.

FIG. 103.—Good and bad practice in installing vents. (*Hoover Report.*)

points in the stack were observed. The results of some of the tests are shown in Table 70. The base connections are arranged in such an order in the table that the back pressure observed at the lowest floor increases down the columns of the table. It is evident, therefore, that a long-sweep fitting is most effective in reducing pressures and that a short-sweep ell permits the greatest pressures to develop. It is interesting to note that, unexpect-

edly, the effect on siphonage is similar to the effect on back pressure and that the use of the long-sweep fittings results also in minimum siphonage.

152. Installation of Vents.—In the installation of any vent care should be taken to avoid clogging. In Fig. 103, taken from the Hoover Report, are shown various methods of installing vents, two of which show poor practice and three show good practice in avoiding clogging.

As a final conclusion with regard to vents the Hoover Report concludes:*

1. That the developed length of an unvented horizontal waste be limited to 6 ft.

2. That the developed length of an unvented horizontal waste from a washbasin or other oval-bottomed fixture be limited to 4 ft. for traps with nominal 2-in. seals and 6 ft. for nominal 3-in., or more, seals. (The committee later agreed on a maximum developed length of 5 ft. permissible for horizontal unvented waste pipes for all fixtures.)

3. That a horizontal section of a vented portion of a waste pipe be limited to 6 ft. except when the vent is the continuation of a vertical portion of the waste, in which case it may be extended to $d = \frac{b}{a}c$ (see Fig. 103) section b being in general the length necessary to make the connection from the fixture to the vertical section c in the partition or wall, limited always by the condition pertaining to an unvented horizontal waste.

4. That whenever practical a vent be the continuation of a vertical section of the waste.

153. Roof Extensions.—In the installation of a soil, waste, or vent stack it is either carried up through the roof independently, as shown in Fig. 112, or the vent stack may be revented (connected) into the soil or waste stack which is carried through the roof as shown at B in Fig. 96 or at H or H' in Fig. 113. The pipe must be carried full size or larger through the roof and should terminate within 12 in. of the roof unless the latter is accessible to the residents in the building. Under the latter condition the pipe should extend at least 7 ft. above the roof and the top should be covered with a durable and strong metal screen to prevent the dropping of articles down the pipe. Such long pipes may require special protection against clogging by hoar frost. Where there is danger from closure by frost no pipe less than 4 in. in diameter should extend through the roof.

* Page 146.

The opening in the roof is made rain-tight, somewhat as indicated in Fig. 104, by the use of flashing, which is described in Sec. 179, and Sec. 9 of Appendix I. On shingle roofs the flashing is extended under at least two courses of shingles above the vent pipe. On sloping roofs covered with tar paper similar construction is used. On flat roofs of tar, asphalt, or cement the flashing is placed between courses of the roofing material and the finishing course placed over it. On metal roofs the flashing is soldered to the metal.

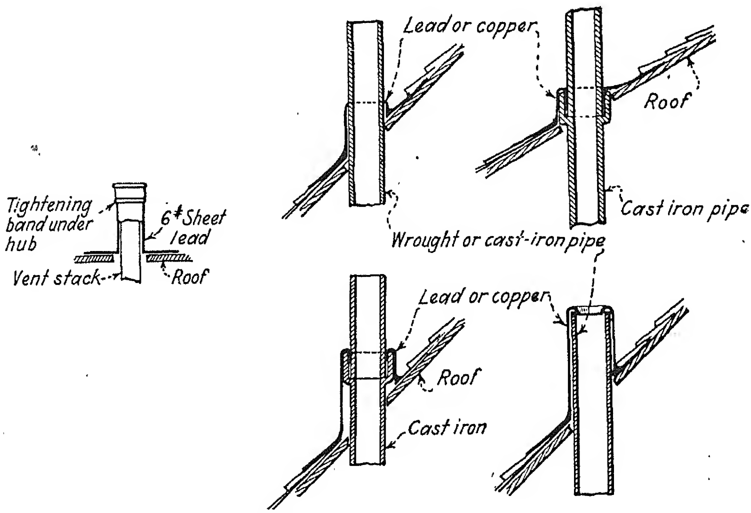


FIG. 104.—Illustrating the use of flashing around a soil or vent pipe passing through a roof. (*From Plumbers Trade Journal*, Apr. 15, 1925.)

154. Frost Protection.—Protection against frost may be obtained by increasing the size of the pipe at least 12 in. below the roof and continuing the increased size through the roof. The increase in size should be made by means of a long increaser. In very cold climates the flashing may be carried up outside of the vent pipe, leaving an annular air space of 1 in. or more between the pipe and the flashing. This air space is open at the bottom to the heat within the building. The upper end of the flashing is bent over and calked into the bell at the top of the cast-iron vent pipe. Another method, less wasteful of heat from the building, is to encase the vent pipe in a brick, tile, or other pipe protection and to pack the space between the two pipes with a good non-conductor of heat. The vent-pipe opening should

not be placed near a chimney on account of the danger of down drafts carrying odors into the building. It should be placed at least 12 ft. away from any opening into a building.

155. Cowls.—Cowls, as illustrated in Fig. 105, are sometimes placed on the top of stacks to prevent down drafts or the dropping of objects down the stack as well as to increase the draft up the stack. Their general use is not to be recommended, however, as they may stick, refusing to turn with the wind, thus increasing rather than preventing down drafts. They are also more con-

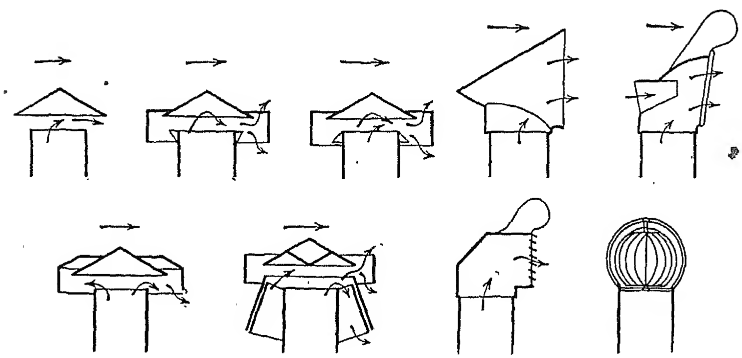


Fig. 105.—Types of ventilating cowls used on plumbing stacks. (*From Plumbers Trade Journal*, Feb. 15, 1925.)

ducive to clogging by frost and to the building of birds' nests in the end of the pipe.

156. Vent Terminals.—The roof terminal of any stack or vent should be more than 12 ft. horizontally from any door, window, air shaft, or other opening through which air may enter the building, or if the pipe must terminate within less than 12 ft. of such an opening the pipe should be extended at least 3 ft. above the opening.

157. Connections between Vent Pipes and Drainage Pipes.—The connection between vent pipes and drainage pipes must be located and designed with care and intelligence to avoid undesirable results. The connection of the base of all vent stacks to drain pipes is necessary in order to prevent the accumulation of rust and other material in the vent pipe. Connections between vent stacks and branch vents should be made above the highest fixture vented by the branch vent pipe in order to prevent the waste water from any fixture from discharging through the vent pipe as the result of the clogging of the drain pipe. The connec-

tion of a revent with a stack may be made by means of an invertec Y, as shown in Fig. 95, or a sanitary Y as shown in Fig. 96 Where a by-pass vent is constructed the vent connections shoul be made as shown in Fig. 101 to prevent water from the stacl from entering the vent pipe. No vent pipe should connect into drain pipe on the house side of a trap as this will provide a untrapped connection between the house and the sewer.

158. Pipe-joining Materials and Their Use.—The types o joints used in pipes and the materials used for making the joint tight are listed in Table 71. In addition to the joints listed in th

TABLE 71.—MATERIALS USED IN PIPE JOINTS

Pipe material	Type of joint	Materials used
Cast iron to cast iron	Bell-and-spigot	Oakum and lead wool or poured lead
Cast iron to cast iron, wrought pipe, brass, or copper	Flanged	Rubber, copper, o asbestos gasket
Wrought pipe to wrought pipe	Threaded	Graphite, lead com pounds, or lampwicl
Brass or copper, to brass, copper, cast iron or wrought pipe	Flanged	Machined, rubbe asbestos, or coppe gasket
Brass or copper to brass, copper, cast iron or wrought pipe	Threaded	Graphite, lead com pounds or lampwicl
Lead to lead, brass or copper[1]	Wiped	Solder
Vitrified clay to vitrified clay, or cast iron	Bell-and-spigot	Cement, bituminous materials, sulphu and sand
Cast iron to cast iron	Bell-and-spigot (rust)	Iron filings, sal ammo niac, sulphur
Wrought pipe to wrought pipe	Threaded (rust)	Sal ammoniac, sulphu
Cast iron to wrought pipe	Threaded	Graphite, lead com pounds, lampwick

[1] Lead cannot be soldered to cast iron or wrought pipe. A brass ferrule with a threade end is soldered into the lead pipe and screwed or calked into the iron pipe or fitting.

table slip joints requiring no additional material to complete ther are used.

159. Bell-and-spigot Joints in Cast-iron Pipe.—In making a bell-and-spigot joint in a cast-iron pipe, either water pipe or drainage pipe, the pipes are first placed in position and supported there. An oakum gasket from 1½ to 1 in. thick, is calked tightly into the bell and around the spigot with a calking tool and hammer such as are shown at *C* and *D* in Fig. 32. The calking must be accomplished with skill as there is danger of breaking the fitting if it is struck too hard. After the oakum is placed, the remaining space in the joint is filled with molten lead which must be calked as it cools because the lead shrinks in cooling. The lead is poured in small quantities so as not to fill the joint all at once. The amount of lead and oakum required for a calked joint are shown in Table 72. The lead is melted over a gasoline furnace and is poured into the joint from an iron dipper, which are shown in Figs. 32 and 33. Where the pipes are in such a position that the bell is not facing vertically

FIG. 106.—Asbestos joint runner.

TABLE 72.—WEIGHT OF LEAD AND OAKUM IN CALKED JOINTS. APPROXIMATE QUANTITIES TO BE USED IN ESTIMATING

Diameter, inches	Pounds of lead per joint		Pounds of oakum per joint		Diameter, inches	Pounds of lead per joint		Pounds of oakum per joint	
	Soil pipe	Water pipe[1]	Soil pipe	Water pipe[1]		Soil pipe	Water pipe[1]	Soil pipe	Water pipe[1]
2	1½ to 2	....	0.21	......	7	5¼ to 7	....	0.73	
3	2¼ to 3	....	0.31	......	8	6 to 8	13¼	0.83	0.44
4	3 to 4	7½	0.42	0.21	10	7½ to 10	16	0.94	0.53
5	3¾ to 5	....	0.52	......	12	9 to 12	19	1.25	0.61
6	4½ to 6	10¼	0.63	0.31					

[1] Thickness of lead 2 in.

upwards an asbestos gasket is clamped tightly around the pipe so as to fit snugly against the bell as shown in Fig. 106, so that its ends do not quite meet at the highest point. Molten lead is poured into the opening and the gasket is removed as soon as the lead has cooled sufficiently. Great care must be taken to have the joint perfectly dry before lead is poured into it as otherwise steam may be generated and the lead blown from the joint with explosive violence. The iron ladle should be warmed before

being dipped into the lead and care should be taken to keep the ladle, the furnace pot, and the lead free from dirt.

Oakum used in bell-and-spigot joints in cast-iron and vitrified clay pipes, consists of loose hemp or material frayed out of old ropes. It is usually soaked in a tar preparation or creosote in order to preserve it and to render it less absorbent of moisture.

Lead, for bell-and-spigot joints in cast-iron pipes, is either pure cast lead, lead wool, shredded lead, or leadite. Lead wool and shredded lead are calked cold into the joint. They have the advantage that they can be used under water or in wet places where molten lead cannot be used. Greater skill and more labor is required in making such joints. In making these joints the lead wool is calked into the joint in strands about ½ in. in diameter and 1 to 3 ft. long, rolled compactly and tapered at each end. Each strand is calked separately and the joints between strands are staggered. Leadite is a composition of iron, sulphur, slag, and salt, finely ground and thoroughly mixed. The material is melted and poured like lead at a temperature of about 400° F. It weighs 118 lb. per cubic foot as compared with lead weighing 708 lb. per cubic foot. Lead requires a temperature of about 327° F. to melt it. Leadite is said to be easier to manipulate than lead; when cast in a joint it is hard and vitreous; it is more elastic than lead; it does not squeeze out in case of pipe movements as does lead; it requires no calking; and, finally, it is less expensive than lead.

160. Flanged Joints.—Flanged joints are made up with gaskets of various materials manufactured, usually, under proprietary names. The materials in most common use include rubber, rubberized cloth, asbestos composition, and copper. Cloth, rubberized compositions, and similar materials are made up about 1/16 in. thick. The copper is corrugated and is made from No. 27 gage sheet metal. Gaskets are called ring gaskets or full-faced gaskets. A ring gasket is shown in Fig. 107. It consists of an annular ring which fits inside of the bolt circle and outside of the outer diameter of the pipe. A full-faced gasket, shown in the same figure, is an annular ring covering the full face of the flange, having holes for the bolts. Gaskets are also used in those types of malleable iron unions which do not have ground seats. Such gaskets are usually of rubber. All of the gasket materials mentioned will make water-tight joints. Considerations of economy and durability must be balanced in the selection between the

various materials. Copper gaskets are high in first cost but their life is practically unlimited. Rubber gaskets cannot be used on hot-water pipe.

Flanged joints are held together with bolts passing through the flanges.

161. Threaded Joints.—Threaded joints require care in the cutting of the pipe and threads. The pipe should be cut square and reamed. To ream a pipe is to remove the burr usually left by the cutting tool on the inside of the pipe. The threads are then cut according to the standards given on page 274. Before the pieces to be connected are joined the pipe end with an outside

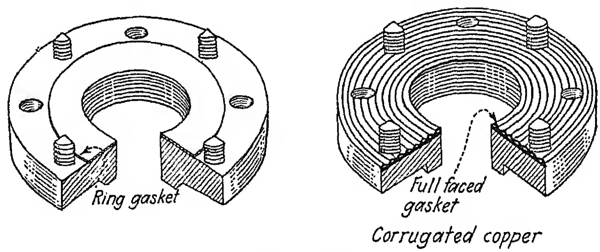


FIG. 107.—Gaskets.

thread should be smeared with some lubricant but not so much that it will protrude into the pipe and, after hardening, obstruct it.

The graphite compounds, or pipe dope, used on joints are generally proprietary articles consisting of finely ground graphite held in suspension or mixed with heavy oil or a light lubricating grease, together with other substances. Such material is applied to the outside threads only and so lubricates and protects the threads that a tighter joint can be secured than without the use of the lubricant. It protects the threads against corrosion and as it hardens it prevents leakage. The Smooth-on products are iron compounds manufactured by the Smooth-on Manufacturing Company of Jersey City. They include joining and leak-stopping compounds for joining pipes and repairing breaks and stopping leaks in pipes and castings. Red lead, white lead, or both, mixed with oil or grease are also in common use as a lubricating, preserving, and tightening compound for threaded joints and are as satisfactory as the graphite mixtures. Lamp wicking, wrapped about the outside threaded end of a pipe is used to some extent in securing tight joints. It is neither a lubricant nor a preservative. It makes a satisfactory joint.

162. Rust Joints.—Rust joints are made in bell-and-spigo cast-iron pipe or in threaded iron pipe where it is desired to mak a tight, permanent joint that will not be affected by the liqui passing through the pipe. In bell-and-spigot pipes the joint i first calked with oakum and is then filled with a mixture c powdered sulphur, 1 part; sal ammoniac, 1 part; and iron filings 98 parts. To make a threaded joint rust a solution of sal am moniac alone is used.

163. Solder or Wiped Joints.—Solder or wiped joints are ver ancient in the history of plumbing and it was from their makin and work in lead that the plumber received his name. In spit of this fact wiped joints are falling into disuse because of th greater ease and less skill involved in making other types c joints. To wipe a joint successfully requires skill and practice no amount of reading will make perfect. The following is th procedure in making a wiped joint. It will be helpful in attainin skill through practice.

To make a wiped joint[2]: First, prepare both ends of the pipe a in Fig. 108. Rasp one end to a taper. Rub chalk over it for length of about 6 in. to remove the grease. Then paint the pipe with plumber's soil for about 4 in. When the soil is dry shave about 1¼ in. of the end of the pipe clean with a shave hook. Rub mutton tallow, without salt, over the shaved portion to prevent tarnishing. Bell out the other end of the pipe with a turn pin. Rasp off the edge as shown. Chalk, soil, shave, and grease a before.

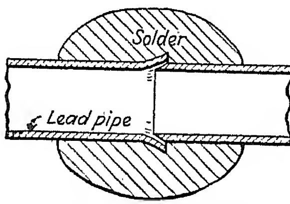


FIG. 108.—A wiped joint.

Second, push the ends of the pipes together as in Fig. 108 an hold them firmly in place. Allow a clear space of at least 4 ir under the joint.

Third, heat the solder until it chars, but does not ignite, a piec of paper dipped into it. Stir, and skim off the dross. Get mole-skin or ticking wiping cloth; warm it; grease its workin face; take up a ladle of hot metal; pour it on the top of the join proceed to wipe.

Fourth, hold the cloth under the joint with the left hand a the solder is poured slowly to and fro over the top of the join Catch the falling metal in the cloth and pat it up against th

underside of the joint to heat and tin it. Continue pouring metal slowly on the joint until it becomes plastic and runs off. Keep it plastic a few seconds working it around and up on the joint. When enough heat has been obtained in the joint and metal is all plastic above, below, and all around the joint, form the plastic mass into a wiped joint of the shape of an egg, wiping the edges clean so that when finished it will resemble Fig. 108. The finishing touches, which really give the egg shape and make the joint smooth, are accomplished by curving the cloth and smartly swinging it around the joint, first up one side, then up the other, and finally drawing smartly across the top to wipe off any surplus.

It takes practice, not reading, to do it.

Solder for wiping lead joints, either lead to lead, or lead to any other metal, is an alloy of lead and tin. The composition of solders used in the trade are shown in Table 73. Standard specifications for soldering metal are given in Sec. 15 of Appendix I. An excellent exposition of the metallurgy of solder is presented in "Plumbers Handbook" by Dibble. The fluxes and tools used in soldering various metals are shown in Table 74.

TABLE 73.—COMPOSITION OF SOLDERS

Variety	Hard			Soft			Fusing point, degrees Fahrenheit
	Tin	Lead	Silver	Tin	Lead	Silver	
Spelter, hardest	1	2	......	......	......	......	700
Spelter, hard	2	3					
Spelter, soft	1	1	......	......	......	......	550
Spelter, fine	8	8	1				
Silver, hard	......	1	4				
Silver, medium	......	1	3				
Silver, soft	......	1	2				
Plumber's, coarse	......	......	......	1	3	......	480
Plumber's, ordinary	......	......	......	1	2	......	440
Plumber's, fine	......	......	......	2	3	......	400
Tinner's	......	......	......	1	1	......	370
For tin pipe	......	......	......	3	2	......	330
For tin pipe	......	......	......	4	4	1	

See also Sec. 15 Appendix I.

TABLE 74.—FLUXES

Flux	Used with	Metals to be joined
Resin	Copper bit or blow pipe	Lead, tin, copper, brass, and tinned metals
Tallow, unsalted	Blow pipe or wiping process	Lead, tin, or tinned metals
Sal ammoniac	Copper bit or blow pipe	Copper, brass, iron
Muriatic acid	Copper bit	Dirty zinc
Chloride of zinc	Copper bit or blow pipe	Clean zinc, copper, brass, tin, tinned metals
Resin and sweet oil	Copper bit or blow pipe	Lead and tin metals
Borax	Blow pipe	Iron, steel, copper, and brass

164. Cement Joints.—Cement joints for vitrified clay pipe are made with Portland cement either neat, *i.e.*, cement and water only, or as a grout, *i.e.*, a mixture of cement and sand with water, mixed to the consistency of a stiff paste.

Cement joints should be made in vitrified clay pipes, laid outside of a building, as follows:

A stiff layer of mortar consisting of one part of Portland cement to one part of sand should be spread evenly over the lower third of the inner circumference of the bell. The next succeeding pipe should then be inserted and brought to line, and grade. For the best results a gasket of oakum not less than ½ in. in thickness should be laid against the hub of the pipe so as to be wedged tightly between the hub and spigot, thus preventing the entrance of mortar into the barrel of the sewer.

The spigot should fit against the shoulder and the invert should form a true and even surface. The space between the hub and the spigot which is not occupied by the oakum gasket should be entirely filled with mortar, thoroughly pressed and tamped in at the bottom, sides, and top and every precaution taken to secure a water-tight joint. The mortar should be applied with a rubber mitten and a small sharp-pointed trowel. It should be rammed and compacted with a wooden calking tool. The joint should be finished with a neat and generous bevel of mortar extending to the external circumference of the hub. The interior of each pipe should be scraped clean of all mortar and no foreign

matter should be left within the pipe. No water or sewage should be allowed to pass through the pipe until the cement is thoroughly set.

165. Poured Joints.—Poured joints in vitrified clay pipe are made with cement grout mixed to a very thin consistency; sulphur and sand; and asphalt or a bituminous compound made of vulcanized linseed oil, clay, and other substances, the resulting mixture having the appearance of vulcanized rubber or coal tar.

In making the poured joint with cement grout the pipes are set in place and an oakum gasket is calked into place. The grout is then poured into the remaining space and allowed to set. The joint is not particularly satisfactory as it is prone to crack and is easily broken by movements of the pipe. It is more satisfactory than an ordinary cement joint because there is a certainty that the bottom of the joint is properly completed. Since the joints are usually made with the pipes in a horizontal position a gasket must be used around the bell of the pipe in order to hold the cement in place until it has set sufficiently for the gasket to be removed. The joint is, therefore, slightly more expensive than an ordinary cement joint made by hand.

Sulphur and sand are inexpensive, comparatively easy to handle, and make an absolutely water-tight and rigid joint which is stronger than the pipe itself. It frequently results in the cracking of the pipe and is objected to on that account. In making the mixture, powdered sulphur and very fine sand are mixed in equal proportions. It is essential that the sand be fine so that it may mix well with the sulphur and not precipitate out when the sulphur is melted. 90 per cent of the sand should pass a number 100 sieve, and 50 per cent should pass a number 200 sieve. The mixture of sulphur and sand melts at about 260° F., and does not soften at lower temperatures. It is poured into the joints while hot. This requires calking of the joint, the use of asbestos gasket, and care in handling the hot compound.

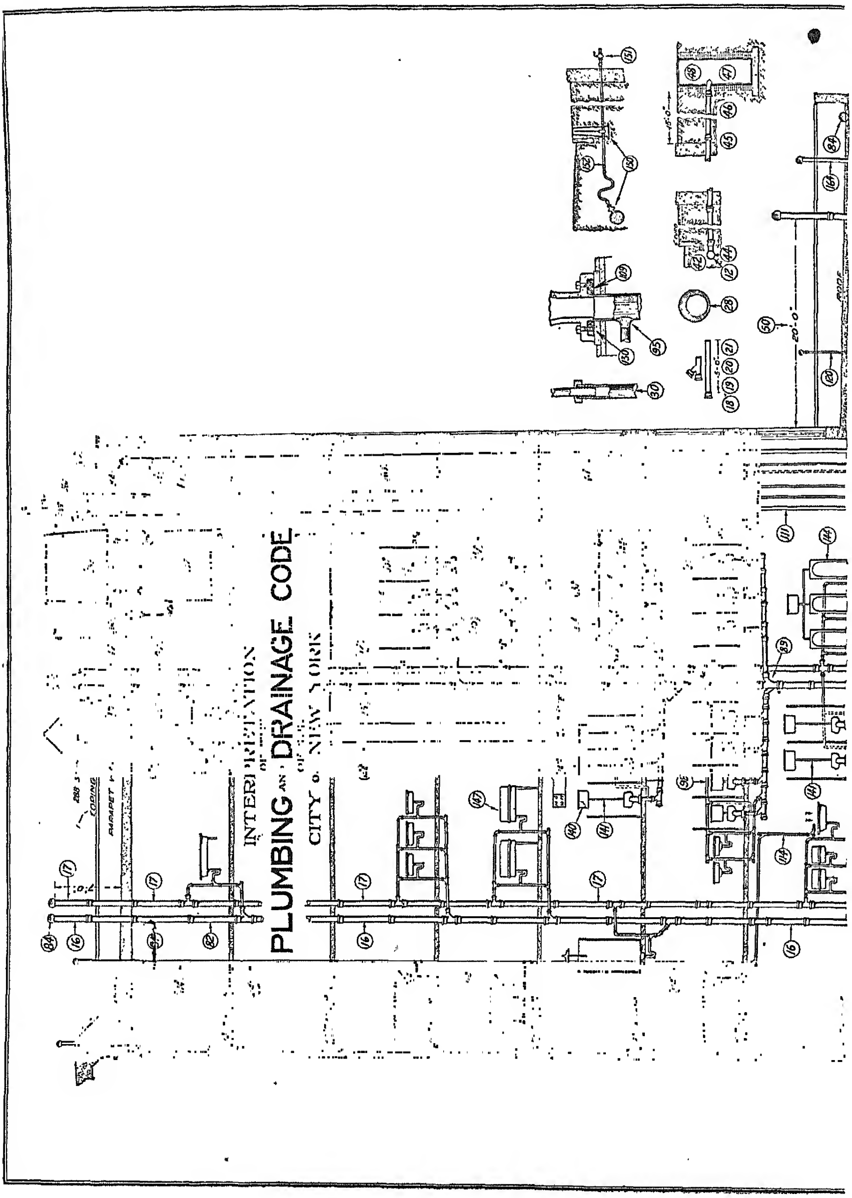
Among the better known of the bituminous compounds are "G.K." Compound, made by the Atlas Company at Mertztown, Pa., Jointite and Filtite manufactured by the Pacific Flush Tank Company at Chicago and New York, and some of the products of the Warren Brothers Company, Boston. These compounds fill nearly all of the ideal conditions for a joint compound in clay pipe except as to cost and ease in handling. If overheated or heated too long they will carbonize and become brittle. In cold

weather they do not stick to the pipe well unless the pipe is heated before the joint is poured. On some work, joints have been poured under water with these compounds but success is doubtful without skilful and experienced handling. An overheated compound will make steam in the joint, causing explosions which will blow the joint clean and an underheated compound will harden before the joint is completed. The materials should be heated in an iron kettle over a gasoline furnace, or other controllable fire, until they just commence to bubble and are of a consistency of fine sirup. Only a sufficient quantity of material for immediate use should be prepared and it should be used within 10 to 15 min. after it has become heated. The ladle used should be large enough to pour the entire joint without refilling.

In making a poured joint the pipes are first lined up in position. A hemp or oakum gasket is forced into the joint to fill a space of about 3/4 in. An asbestos or other heat-resisting gasket, such as a rubber hose smeared with clay, is forced about 1/2 in. into the opening between the bell and the spigot and the melted compound is poured down one side of the pipe, through a hole broken in the bell, until it appears on the other side and the hole is filled. In pouring cement-grout joints a paper gasket is used instead of the heat-resisting material. It is held to the bell and spigot by draw strings. Greater speed and economy can be attained by joining two or three lengths of pipe on the bank and lowering them as a unit into the trench. The pipes are set up in a vertical position and the joints poured without the use of an outer gasket. When a gasket is used it should be removed as soon as possible to prevent sticking.

166. Slip Joints.—A slip joint is made by slipping one pipe snugly into another. A lubricant or joint filler is sometimes spread on the outer surface of the inside piece before it is inserted in the other pipe. As it is not possible to make such joints air tight and water tight under all circumstances they should be used on drainage pipes only on the house side of a trap and on the flush pipe from water-closet flush tanks to the closet bowl. In this location and on lavatory waste pipes the joints are easily made, they will take up vibration or movements between the fixture and the piping without injury to either, and as the water pressure is low leakage does not occur.

167. Examples and Explanations of Practical Installations.—Some of the requirements of the New York City Plumbing Code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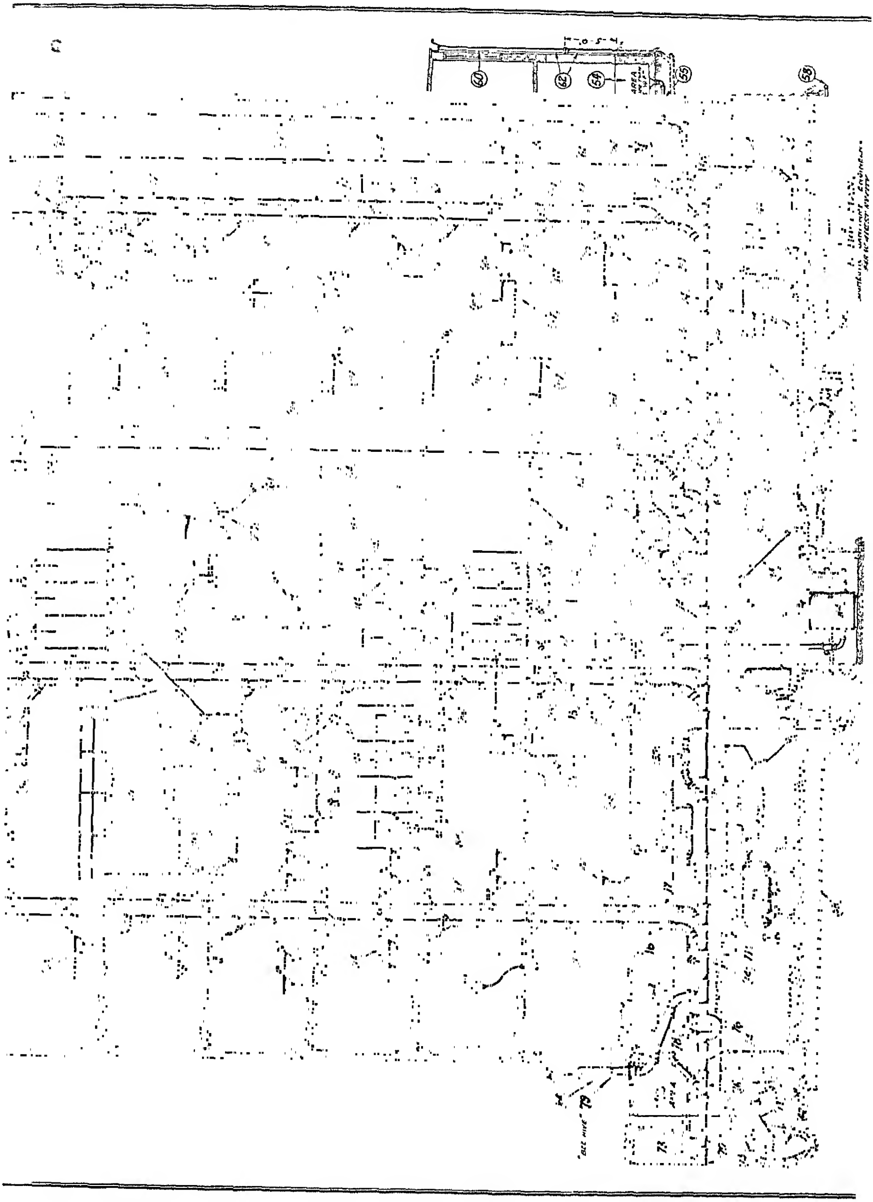

are shown in Fig. 109. This illustrates various details in the roughing-in of drainage systems which are examples of good practice. Figures 94 to 96 and 110 to 113 show some of the requirements of the Model Plumbing Code issued in 1926 by the Illinois State Department of Public Health. The features illustrated in these and other figures are explained as follows:

Figure 95 at *A* and Fig. 110 at *A*.—Scale, rust or other material dropping down the vent pipe will fall into the waste pipe and be washed away (see Sec. 157).

Figure 96 at *B*.—Material falling down the stack will be directed away from the vent pipe. Compare this connection with the inverted Y at *H'* in Fig. 113 and at *B* in Fig. 95. All of these types of connections are found in practice. No vent pipe should be connected at its top to a soil or waste stack (called reventing) below any point of discharge of liquid into the stack.

Figure 110, at *A*.—Where loop vents are used it is desirable to connect the last, or highest, fixture on a horizontal pipe to the vertical portion of the discharge pipe (see Sec. 132) rather than to the horizontal portion. This aids in flushing the vent pipe.

At *B*.—Where loop vents are used on a horizontal waste or soil branch to which more than one fixture is connected, a vent pipe should be taken off the branch pipe between the stack and the nearest fixture, because, when water is discharging down the stack at the same time that a fixture is discharging into the branch pipe, the trap on an intermediate fixture on the branch pipe would otherwise be subjected to unvented pressures (Sec. 132).

At *C*.—When the last fixture on a loop vented waste or soil branch discharges into the horizontal part of the branch pipe the loop vent should be taken off of the branch pipe between the last fixture and the stack. Droppings from the vent pipe will thus be flushed from the waste pipe (Sec. 132).

At *D*.—In Sec. 132, certain restrictions are placed on the use of loop vents because of tests which have shown the limiting capacity of sloping pipes. From Table 58, it is evident that no more than 42 fixture units may be discharged into a 4-in. pipe sloping at ½ in. per foot. Figure 110 shows 39 units thus connected.

At *E*.—The number of fixture units which may be discharged into a waste or soil branch *between* loop vent connections is limited because if a vent, such as at *E*, did not exist and groups of fixtures above and below those fixtures nearest to *E* were discharged simultaneously, the seals on the fixtures nearest to *E* would be broken by the unvented air squeezed in between the two discharges (Sec. 132).

At *F*.—The capacities of horizontal waste branches are given in Sec. 129, and in Tables 57 and 58.

At *G*.—Vent pipes should not decrease in diameter in the direction away from the waste or soil pipe vented. Since the branch soil pipes vented under the conditions shown here also serve, at times, as vent pipes no loop vent pipe, as shown here, can be smaller than the branch soil pipe vented.

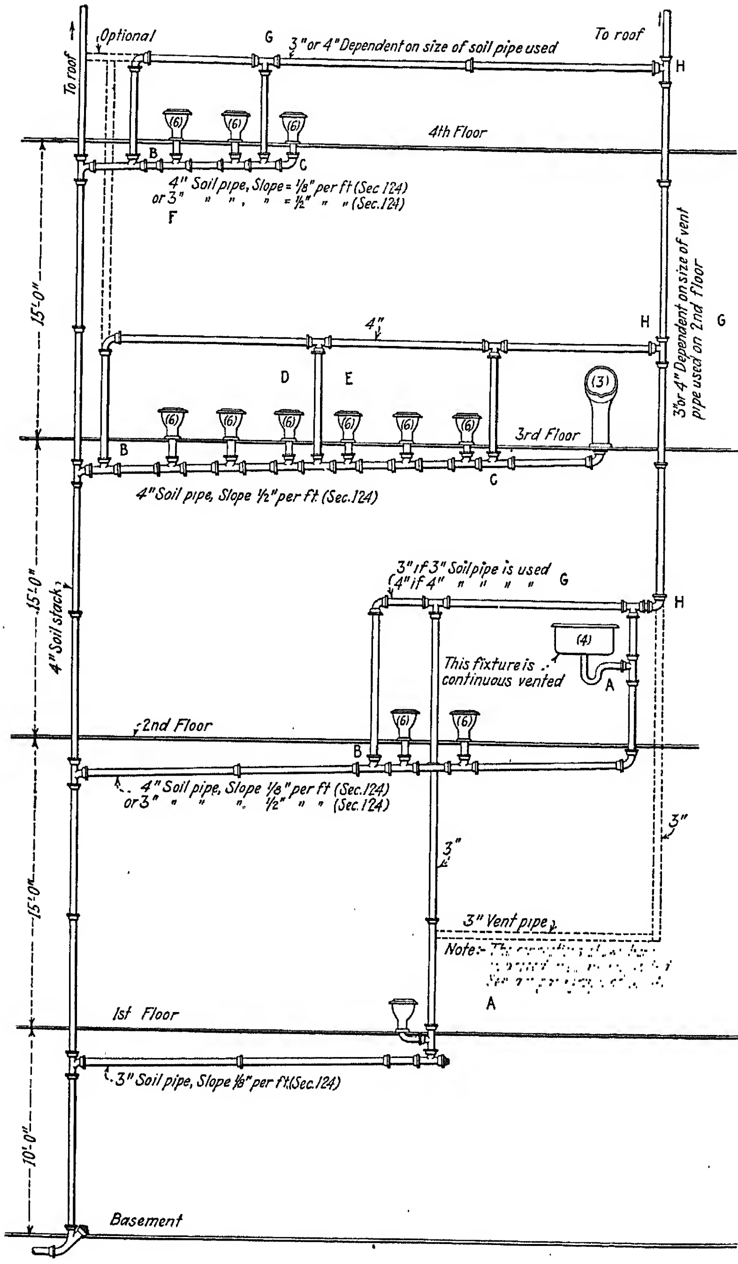

FIG. 110.—Illustrating vent and drainage pipe installations.

The numbers in parentheses on the fixtures indicate fixture units. The sections referred to are in the Model Plumbing Code, recommended by the Illinois Department of Public Health.

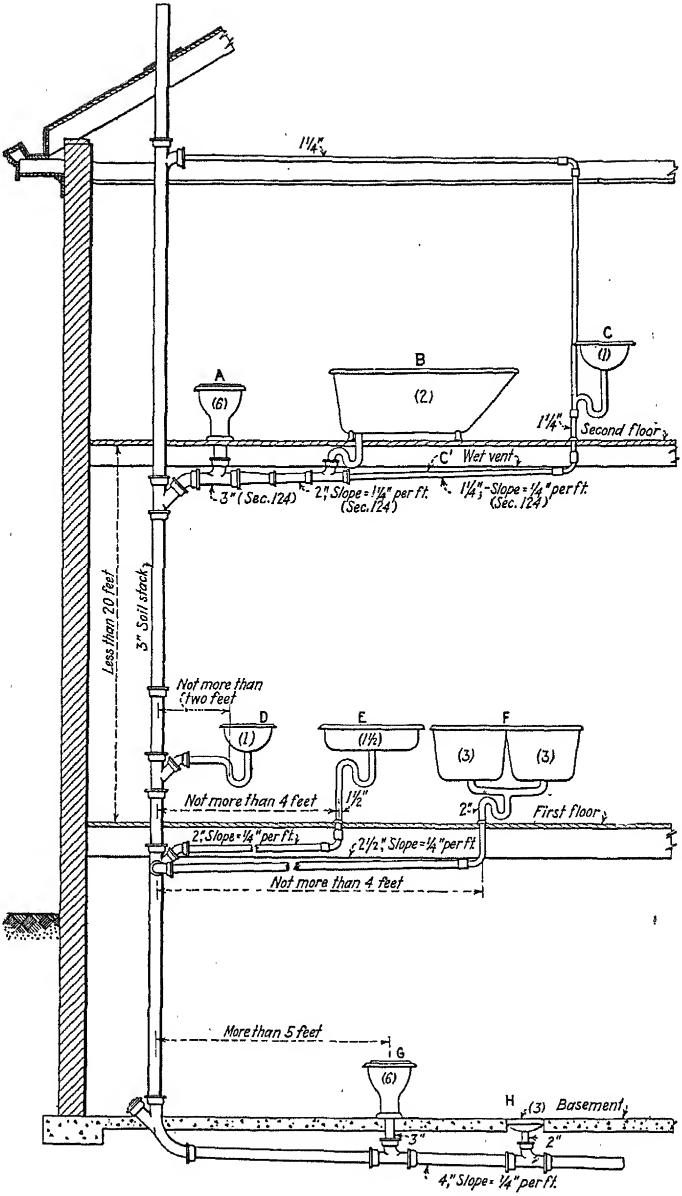

FIG. 111.—Illustrating a wet vent and installations without vents.
Numbers in parentheses represent fixture units. Sec. 124, referred to, is in the Model Plumbing Code recommended by the Illinois Department of Public Health.

At *H*.—Branch vents should connect to vent stacks at least 6 in. above the highest fixtures vented by the branch vent pipe. Under such conditions if the waste or soil branch from any fixture becomes clogged water cannot rise to run through the vent pipe into another fixture nor can the vent pipe become a discharge pipe (Sec. 157).

Figure 111.—This figure illustrates primarily the conditions under which it is permissible to install fixtures without venting. The operation of plumbing systems under these conditions have been tested and found successful. They are embodied in Sec. 134. Any unvented fixture, waste, or soil pipe must fulfill each and all of the six conditions of Sec. 134B.

At *A*.—This fixture is not vented because it fulfills the conditions of I(2), II, III, IV(1), V, amd VI.

At *B*.—This fixture is not vented because it fulfills the conditions of I(2), II, III, IV(2), V, and VI.

At *C*.—This fixture is vented because it fails to fulfill the conditions of I or IV(2) although it does fulfill II, III, V, and VI.

At *C′*.—This illustrates the requirements of Sec. 131, with regard to a wet vent.

At *D*.—This fixture is not vented because it fulfills the conditions of I(1), II, III, IV(3), V, and VI.

At *E* and *F*.—These fixtures are not vented because they fulfill the conditions of I(1), II, III, IV(2), V, and VI.

At *G* and *H*.—These fixtures are not vented because they fulfill the conditions of Sec. 134C.

Figure 112 illustrates the use of the Tables 57, 59, and 63 to 68 in the determination of drainage and vent-pipe sizes. The installation of three lavatories with a common trap is permitted under Sec. 123. The entire figure presents a generous equipment of plumbing fixtures for a single building.

Figure 113. At *A* and *B*.—No fixture larger than one fixture unit can discharge into a 1½-in. stack because a 2- or 2½-in. branch waste would be called for by more than one fixture unit, which would require, by Sec. 147 which prohibits decreases in size of waste pipes, an equally large stack. Two fixtures of one unit each can be attached to the stack as shown here because, by Table 59, a 1½-in. stack will receive up to eight fixture units.

At *C*.—Only one fixture unit can be attached here because of the limitation of the 1¼-in. branch, in accordance with Table 58.

At *C′*.—This illustrates the requirements of Sec. 137 concerning the method of connecting the base of the vent stack to a soil stack and the method of joining a branch vent above the fixture vented and sloping this vent at not less than 45 deg. with the horizontal.

At *D*.—The restrictions of the footnote under Table 59 limit the discharge into a 3-in. stack at the same point to 36 fixture units. Sec. 134C states that no vent is required here because there are not more than eight fixture units connected to the 3-in. stack above this point.

At *E*.—Under the conditions of Sec. 134C it is permissible to connect to a 3-in. stack in this manner a maximum of eight fixture units with this type of unvented fixture.

At *F*.—The stack must be the same size from the bottom to the roof. It may increase in size in passing through the roof (see Sec. 147 and 153).

At *G*.—No fixture may be connected here as the maximum distance water may fall in a 1½-in. stack above the lowest connected fixture is 50 ft. (see Table 59).

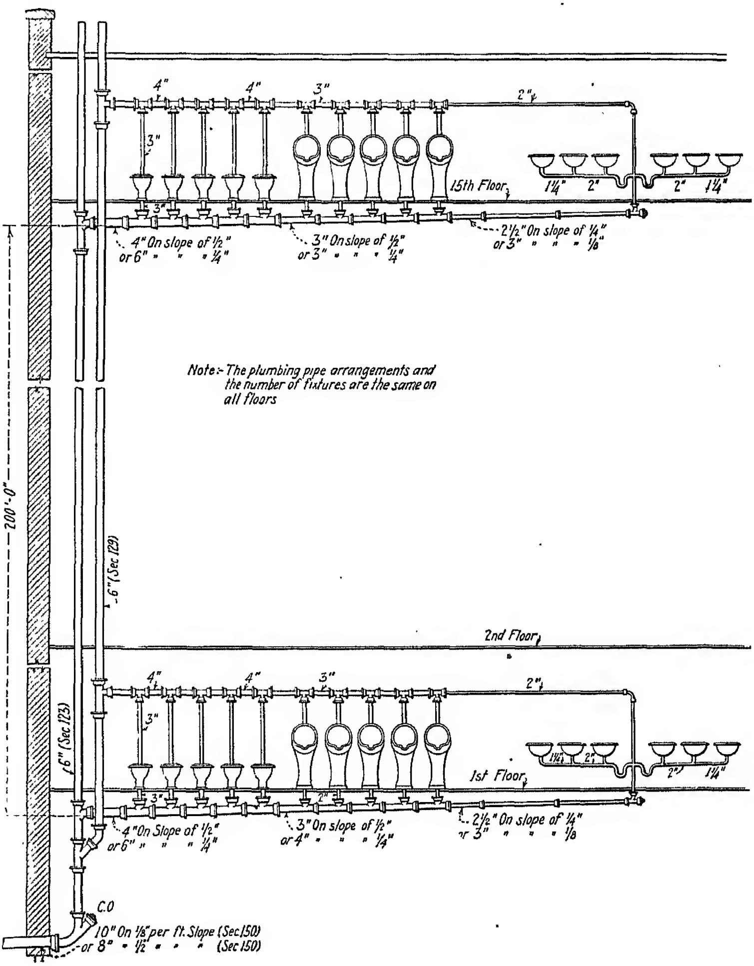

FIG. 112.—Illustrating vent and drainage pipe installation in a tall building. The sections referred to are in the Model Plumbing Code, recommended by the Illinois Department of Public Health.

At *H*.—These fixtures are all unit vented, which is permitted under Sec. 134D. They also fulfil the requirements of Sec. 133 with regard to the distance between a trap and its vent.

At *H′*.—It is permissible to connect a vent stack to a soil stack above all other fixtures (Sec. 153).

At *J*.—A drum trap, or other non-siphon trap, may be used without vent on the bathtub here under the conditions of Sec. 134A. The other fixtures here must be vented because non-siphon traps have not been used on them and none of the other exceptions of Sec. 134 is applicable. The size of each branch vent is the same as the branch waste (Sec. 135).

At *K*.—At least a 3½-in. vent stack must be used under the tables of vent stack sizes in Sec. 136. In this case the water falls about 65 ft. in a 4-in. soil stack from the highest to the lowest fixture, the length of the vent stack is about 85 ft. and 90 fixture units are connected to it.

At *L*.—Each fixture must be vented here as none of the provisions of Sec. 134B is applicable.

At *M*.—No vent is required by any of these fixtures as each fixture fulfills all of the six requirements of Sec. 134B.

At *N*.—Only one trap is required for these three laundry trays under the provisions of Sec. 123, and no vent is required as they fulfill all of the six conditions of Sec. 134B.

At *P*.—No vent should be required on a fixture under the following conditions:

Where a soil, waste, or vent pipe at least 2 in. in diameter connects with a house drain; one water closet, basement, or cellar floor drains, subsoil traps, elevator catch basins, or traps on similar fixtures *need not be vented* provided they enter the house drain 5 ft. or more, in direction of flow, from the base of the lowest soil or waste stack connected to the house drain; provided also that condition IV of Sec. 134B is complied with; and provided further that if the possibility of submerging the end of the house drain or sewer exists a fresh-air inlet shall be placed on the house sewer above the point of highest probable submergence.

In this connection the Hoover Report states:

Storm water, a high tide, or sewer stoppage, may cause the house sewer or even the house drain to be submerged, giving back-pressure effects similar to those produced by admitting roof water to the system. When such complications as this are likely to occur the committee favors a distance of at least 3 ft. between the lowest fixture inlet to the stack and the house drain.

At *R*.—All fixtures must be vented as none of the exceptions of Sec. 134B is applicable. The unit venting of the bathtubs is permitted under this Section. The discharge of the bathtubs into the lower portion of the vent pipe is desirable to flush out the vent pipe.

At *S*.—These illustrate the conditions described in Sec. 183.

At *T*.—Illustrating the requirements of Secs. 153 and 156.

At *U*.—Illustrating the requirements of Sec. 141.

At *U′*.—Illustrating the requirements of Sec. 137.

At *V*.—Illustrating the requirements of Sec. 290.

At *W* and *N*.—The requirements of Sec. 136A permit the use of a drum trap or other non-siphon trap on flat-bottom fixtures where one or more

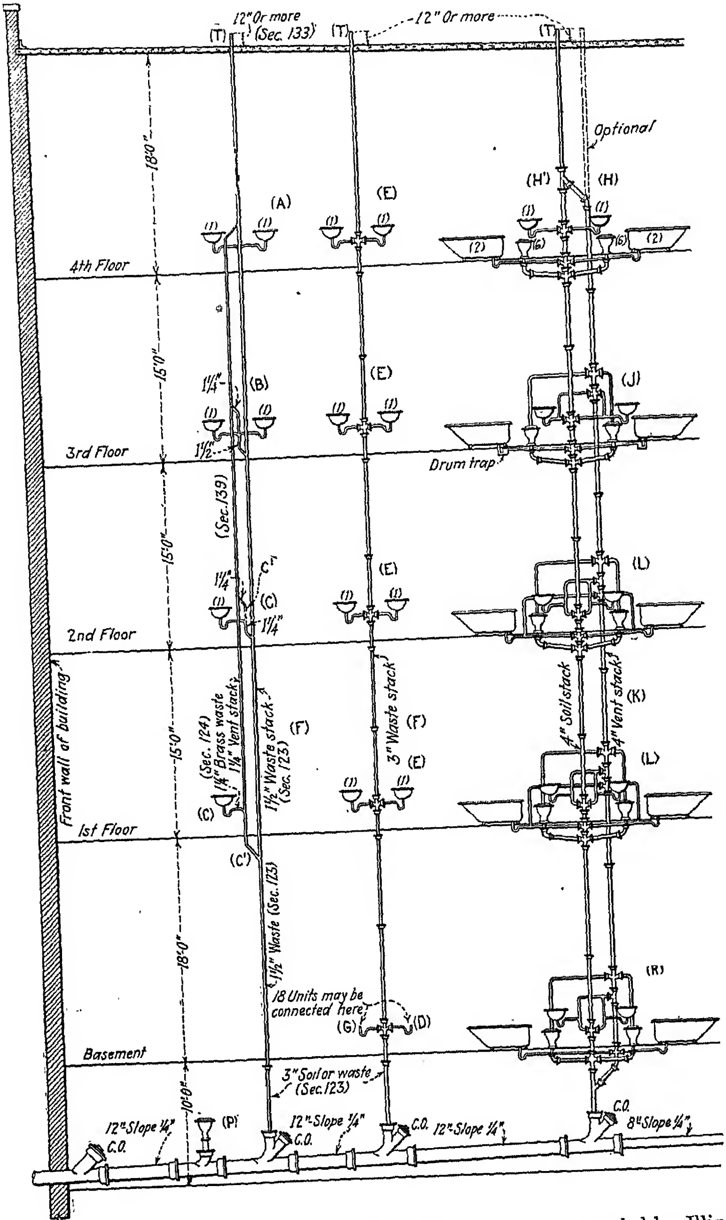

FIG. 113.—Requirements of Model Plumbing Code recommended by Illinois State Department of Public Health. (The numbers in parentheses indicate fixture units.)

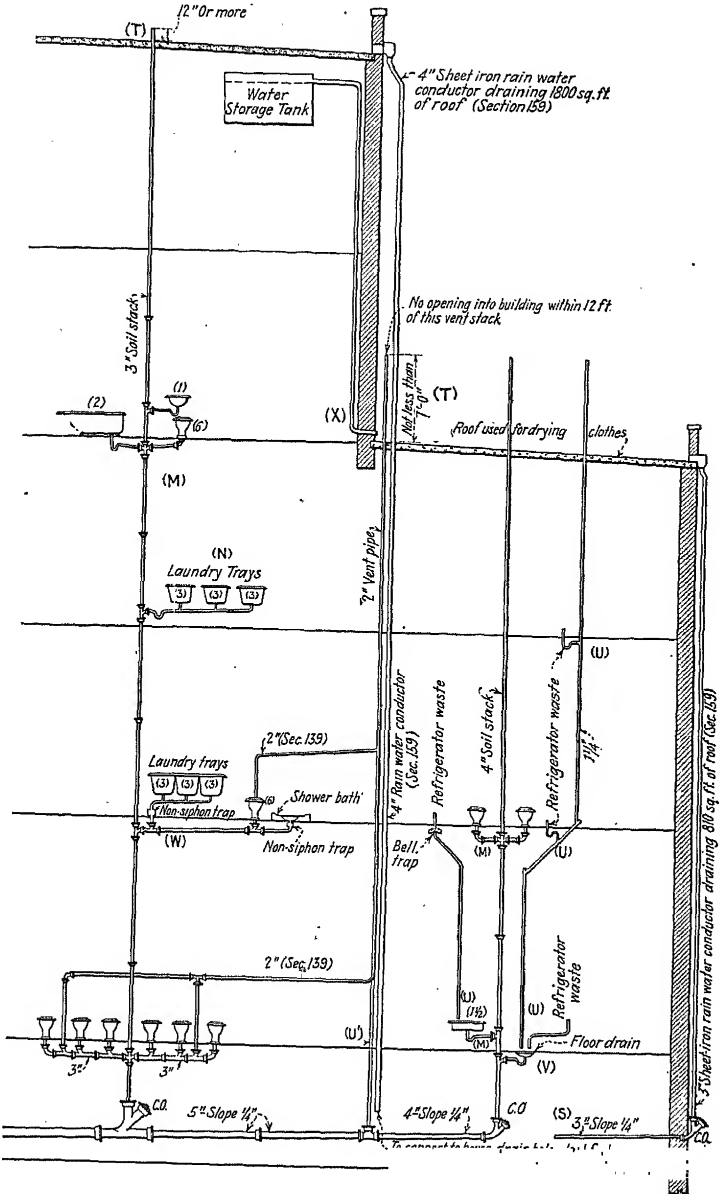

FIG. 113.—Requirements of Model Plumbing Code recommended by Illinois State Department of Public Health. (The numbers in parentheses indicate fixture units.)

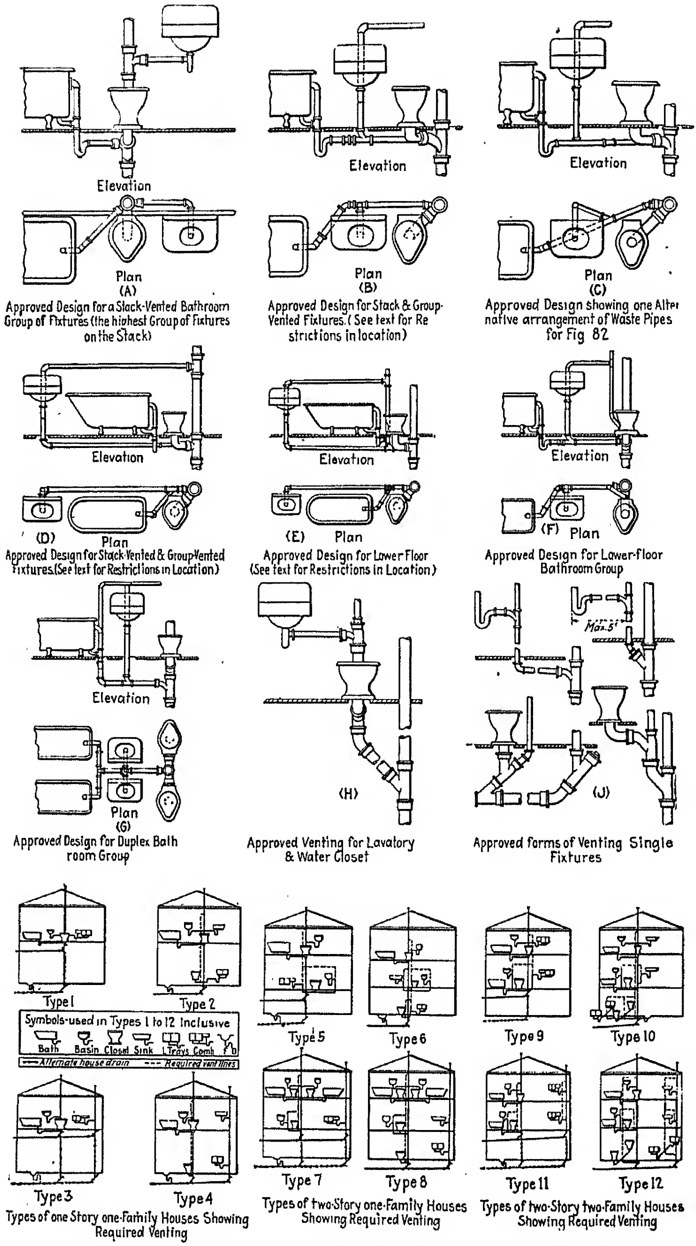

FIG. 114.—Types of plumbing installations approved by "Hoover Report."

fixtures on the same branch waste is vented. A vent is required at the elevation of *W* and not at the floor above at *N* because the fall of water in the soil stack is greater than the fall permitted in the table in Sec. 134A.

The Hoover Report recommends many construction details for small dwelling houses which are illustrated in Fig. 114. The illustrations show details of construction in which the principles and requirements, as determined by the experimental work, are applied to the types of buildings under construction, namely small dwelling houses. The committee states:

We have pointed out that the most efficient drainage will be secured with the most direct wastes consistent with the general requirement to protect the trap seals. It follows that an individual vent installed where one is not needed is not only an added expense but may prove a detriment by reducing the velocity of flow and consequently the scour in the waste or soil pipe thus vented. For these reasons we have given preference to the plan involving the simplest venting. This, in general, involves a close grouping of the fixtures about the stack, assuming that the stack will be located so as to make such grouping within limits of allowable length of unvented wastes. It is recognized that such grouping and length will not always be possible, and alternate plans in the order of preference are given for each type of building represented. The types go from the simplest to the more complex and, in general, for one type will serve equally well in the same position in a simpler type of building. It will be observed that the plans, Figs. *A* to *J*, in connection with Figs. *K* to *M* in Fig. 114 graphically represent a summary of conclusions insofar as they apply to small dwelling-house construction. The maximum developed length of all horizontal unvented waste branches is limited to 5 ft. with slopes of ¼ to ½ in. per foot.

Design *A* is suitable for the highest group of fixtures on the soil stack. A kitchen sink, with an independent waste branch connecting to the stack above the water-closet branch, may be added to the group without other change. Design *B*, design *C*, and design *D*, are alternative layouts recommended for the highest group of fixtures when the desired location of fixtures cannot be secured with design *A*. These are not adapted to as many variations in order of arrangement as design *A*, but permit some which cannot be secured in design *A*, such as the location of the lavatory on the opposite side of the bathroom from the soil stack. A kitchen sink may be added to the group with the same restrictions as before. Design *B* will also serve with comparative safety on a lower floor when the possible discharge from above does not exceed one bathroom group plus a kitchen sink or 10½ fixture units. Design *E* may be used on a lower floor under the same conditions. Design *F* may be used on a lower floor when the possible discharge from above

exceeds 10½ fixture units. Design *G* represents approved duplex arrangement for the highest group. Two kitchen sinks or two combination fixtures with wastes connecting above the water-closet branches may be added without other changes. Design *H* shows approved venting of a lavatory and water-closet group on a lower floor.

Figure *J* represents approved forms of venting single fixtures with wastes connecting independently to the stack to be employed when necessary to vent in any position and approved forms of venting water closets when connected to the stack near the base and when connected independently to the house drain.

Figures *K* to *M* represent types for small dwellings which we believe to be sufficiently varied to illustrate all types within the scope of the present report. Many variations of each type might be made without in any way changing the principles or the requirements. In general, a fixture, or a group of fixtures, may be omitted from a lower floor of any type without changing the requirements in venting for other fixtures on the same floor or floors above.

The designs and requirements in venting are given for the 3-in. soil stack. This is not to be interpretated as a requirement for the use of a 3-in. soil stack. It has been found to be serviceable beyond the requirements for any of the types of buildings within the scope of the plumbing committee's report and its employment in preference to a 4-in. soil stack introduces a saving in material, labor, and space. It has been suggested that the employment of a 4-in. soil stack would permit a reduction in the venting required for a 3-in stack. The experiments so far indicate that this would not be true and that, in general, where vents are required for a 3-in. stack they would also be required for a 4-in. stack. Theory indicates that in many cases larger vents would be required for a 4-in. than for a 3-in. stack with the same fixtures installed on both.

The 3-in. stack offers distinct advantages over the 4-in.

168. Inspections and Tests.—After the completion of the roughing-in of a plumbing system it is customary to subject the system to test to locate leaky connections or faulty installations, and upon the completion of the setting of the fixtures a further test is made to locate leaky traps or other unsatisfactory conditions. Where the best quality of work is desired tests should be made frequently during the progress of construction. This assures more careful work on the part of the workmen and where repairs are necessary they are more easily made than after the completion of the building.

169. The Water Test.—The tests used are the *water test*, the *air test*, the *odor test*, and the *smoke test*. The first two are used

on the completion of the roughing-in when high pressures are desired and the last two are used for finishing tests under low pressures.

In making the water test all openings in the drainage pipes are closed except at the tops of the stacks. The openings are closed by means of test plugs, one type of which is illustrated in Fig. 115. The plug is inserted in the open end of a pipe or fitting so that the heavy rubber gasket fits snugly all around. Handle *A* is then screwed down while handle *D* is held motionless. Washer *B* is thus forced down onto the rubber gasket *C* causing it to expand against the side of the pipe. A somewhat similar device, suitable for tests where the pressures exceed 50 ft. of water, is held on the pipe by means of a collar clamped around the pipe.

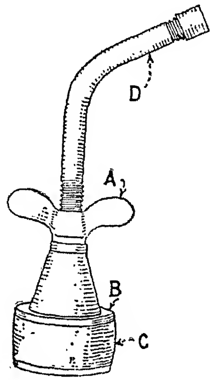

FIG. 115.—Test plug.

When a test is to be made on a plumbing system already connected to the sewer and a main or running trap is in place on the house drain the trap can be plugged by a special trap testing plug which is usually supplied with a valve through which water can be discharged into the plumbing pipes, or the trap can be filled with well-tamped clay and water put into the pipes through some other opening. Where there is no running trap the house drain can be plugged by inserting a test plug through a cleanout opening, or, as a final resort, a section of the pipe may be broken out.

When all openings, except at the tops of the stacks, are closed, water is run into the pipes until it overflows from the top of a stack. The water may be discharged into the top of a stack by means of a hose, or through a connection temporarily soldered in a cleanout opening, or other convenient opening, or through the hollow handle of specially made test plugs. The dropping of the level of the water, after the pipes are full and the supply has been cut off, will indicate a leak which must be found by inspection. All parts of the system should be subjected to a pressure of at least 10 ft. of water. It is not desirable to use pressures over 30 to 40 ft. of water. Higher stacks should be tested in sections of 10 to 40 ft. In very tall buildings this necessitates the making of tests beginning at the top section. The top section is then connected to the next lower section and the pipes are filled to a

height 10 ft. above the connection between the two sections. In this manner no portion of the pipe will be subjected to a pressure of less than 10 ft. of water.

170. The Air Test.—In making the air test all openings are closed and an air pressure of at least 5 lb. per square inch is exerted in the pipes. The falling of the pressure, as shown by a sensitive gage attached to the pipes, will indicate a leak. An air leak can usually be detected by sound. Where but little or no sound is made and a leak is suspected its location can be found accurately by applying saliva or soap suds to the suspected spot. Air tests are more useful in cold weather when there would be danger of the water freezing. They are not so simple of application as the water test, however, and the discovery of the location of leaks is sometimes more difficult but they do give a more even pressure throughout the plumbing system.

In making final tests the highest permissible pressure is about 1 in. of water. After all openings have been closed, if this pressure can be maintained without continuous pumping the system can be considered as air tight. If found to be not air tight by this test it is next necessary to locate the leak. The smoke test or the odor test may be helpful.

171. The Smoke Test.—In making the smoke test a thick smoke is made by burning oily waste, tar paper, or similar material in the combustion chamber of a smoke-test machine. The machine is connected to the lower end of the drainage system and the bellows are then operated to fill the pipes with smoke. When the smoke issues from the top of the stack the stack is closed with a test plug and the pressure run up to 1 in. of water. An inspection is then made to locate smoke or odor issuing from leaks. As the leaks are sometimes too small for the escaping smoke to be seen, windows and doors should be closed so as to retain the odor of the escaping smoke. The leak then can be found by applying soap suds to suspected places.

172. The Odor Test.—The odor test is usually made by the use of oil of peppermint. In applying this test the outlet end of the drainage system and all vent openings except the top of one stack should be closed. About one ounce of oil of peppermint for every 25 ft. of soil stack, but never less than 2 oz. is emptied down the stack, followed by a gallon or more of boiling water. The top of the stack is closed immediately and the leak searched for by the aid of the sense of smell. The man who has poured

the peppermint into the stack should not enter the building until after the search has been completed and no searcher for the leak should have been in recent contact with oil of peppermint. The peppermint test is more simple than the smoke test but its results are not always satisfactory because no pressure has been created in the pipes to force the odor through the leaks.

References

1. *Illinois Master Plumber*, January 1926.
2. "How to Wipe a Joint," *Plumbers Trade Jour.*, Vol. 75, p. 36, 1923; and Vol. 78, p. 436, 1925.

CHAPTER XI

SEWAGE EJECTORS, RAINFALL, AND HOUSE SEWERS

173. Types of Ejectors.—Drainage and sewage from those parts of a building which are below the level of the sewer must be discharged into a sump and ejected therefrom. There are three types of pumps used principally for this purpose: centrifugal, air displacement, and water or steam ejector. Piston and plunger pumps are usually unsuitable for such service because of their inability to handle the solid particles encountered in sewage. These pumps are usually controlled automatically, the control being by means of a float which sets the pump into motion when the sump is full and stops the pump when the sump is empty. Apparatus for ejecting sewage should be installed in duplicate so that when one pump requires repairs or cleaning the other pump can be in operation.

174. Capacities of Sumps and Ejectors.—The capacity of the pump is dependent upon the rate and fluctuations of drainage flow and the capacity of the sump. Where the rate of flow of drainage is constant the pump should have the same capacity as the average rate of drainage flow and only a small suction well is needed. If the rate of drainage flow fluctuates widely and only a small sump is used the pump must be large enough to handle the maximum rate of drainage flow. Where there is a large average rate of flow and wide fluctuations it is economical to construct a large sump thereby making it possible to install a smaller pump. If the fluctuations and the rate of drainage flow are known exactly, it is possible to select the capacity of the pump and sump for the greatest economy by the construction of a mass diagram. The fluctuations and rates of flow are seldom known, however, with sufficient accuracy to justify such a study. In the ordinary installation in the basement of a building where an overflow of sewage or drainage would be disastrous, the pump should have a rated capacity equal to or greater than the estimated maximum rate of flow and the sump should be of such a size that it will require about 15 min. to 1 hr. for it to fill under the maximum

rate of flow; the longer period of storage being used for smaller installations. Where automatic control is not used the sump should be large enough to provide 24-hr. storage. More than 24-hr. storage is undesirable because of the danger from extreme putrefaction of the sewage.

175. Centrifugal Sump Pump.—A centrifugal pump for discharging drainage from an open sump is shown in Fig. 116. The principles of the selection and installation of centrifugal pumps are discussed in Sec. 34. It is stated there that there is

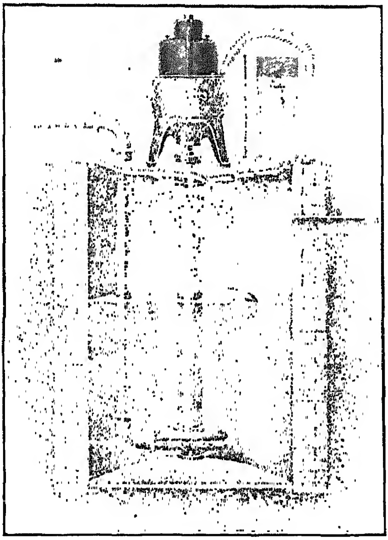

Fig. 116.—Electrically driven automatic sump pump. (*Morris Machine Works.*)

no practical limit to the capacity or pressure which can be obtained from such pumps. They are adapted to the handling of liquids containing solids because of the absence of valves and the large ports in the mechanism. They should be protected by screens on the suction pipe, however. The pump cannot be operated without attention because the screen will need cleaning and the pump will need lubrication.

176. Air-displacement Sump Pump.—An air-displacement pump is shown in Fig. 117. It operates as follows: Sewage enters the reservoir through the inlet pipe at the left, the air displaced being slowly expelled through the air exhaust which is open to

the atmosphere through a vent pipe. The rising sewage lifts the float *D* which opens the valve in the pipe above the reservoir when the reservoir fills. The opening of the valve admits compressed air to the reservoir. The air pressure closes the air exhaust and the inlet valve at the left and ejects the sewage through the discharge valve *B* and pipe at the right. As the chamber *C* drops with the descending sewage it shuts off the air supply and opens the air exhaust through the small pipe at the top center.

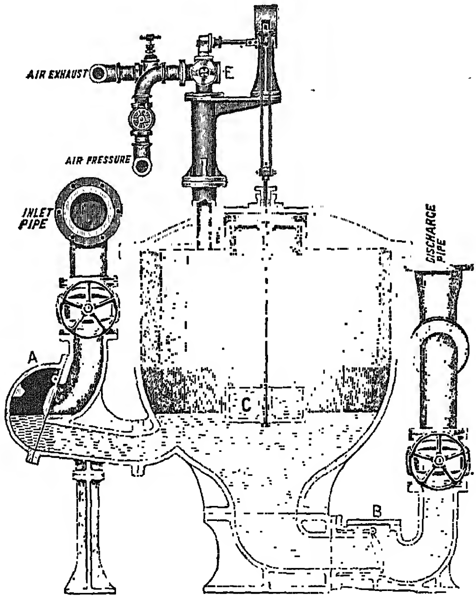

Fig. 117.—Compressed-air sewage ejector. (*Yeoman Brothers Co.*

Sewage is prevented from flowing back into the reservoir by the check valve in the discharge pipe. Ejectors operating on this principle include the Ellis, the Pacific, the Priestman, and the Shone.

The capacity of air tanks and the intensity of air pressure should be so proportioned and the air compressors so designed that there will always be a sufficient volume of air at a pressure sufficient to raise all the sewage or water in the receiving sump at least 50 per cent higher than the maximum lift required.

Such a pump is particularly adapted to the removal of sewage because of the closed chamber in which it operates, the absence

of moving parts in contact with the sewage (except for the float and the check valves), and the full size of the inlet and the discharge ports. They will operate with little or no attention and require no lubrication. Compressed air is needed, however, and the operation of the compressor is sometimes an insurmountable obstacle to a small installation. The capacities of air compressors required for the operation of these pumps are stated in Table 75. These pumps are available in capacities from 50 to 1,000 gal.

TABLE 75.—APPROXIMATE CAPACITIES OF AIR COMPRESSORS REQUIRED TO OPERATE AIR-DISPLACEMENT PUMPS

Water pressure pounds per square inch	Cubic feet free air per gallon water	Water pressure pounds per square inch	Cubic feet free air per gallon water	Water pressure pounds per square inch	Cubic feet free air per gallon water	Water pressure pounds per square inch	Cubic feet free air per gallon water	Water pressure pounds per square inch	Cubic feet free air per gallon water
5	0.179	40	0.497	70	0.815	100	1.043	130	1.316
10	0.224	50	0.588	80	0.861	110	1.134	140	1.407
20	0.315	60	0.679	90	0.952	120	1.225	150	1.498
30	0.406								

per minute. The capacity of the air compressor is dependent on its efficiency, the height of lift, and the quantity of sewage to be lifted. The following formula will give the approximate capacity of the air compressor

$$A = \frac{S(34 + h)}{255},$$

in which A = the cubic feet of free air per minute drawn in by the air compressor, *i.e.* the capacity of the compressor.

h = the lift, in feet, against which the sewage is to be discharged.

S = the rate of flow of the sewage during discharge in gallons per minute.

It is customary to place an air receiver between the compressor and the pump so as to permit the use of a smaller compressor operating for a longer period of time. The efficiency of the pump is measured by the efficiency of the air compressor. The use of air-displacement pumps is restricted to locations where the mechanical equipment of the building warrants the installation of an air compressor.

177. Water-ejector Sump Pump.—A drainage pump operated by a water ejector is illustrated in Fig. 118. It operates because the velocity of water passing through the jet is retarded by the expansion of the stream beyond the jet. The stream is expanded by the increase in the size of the channel beyond the throat or narrow section of the jet. The expansion of the jet creates a vacuum which causes a relatively high suction on the discharge pipe. The velocity energy of the water is converted into pressure energy which is available for lifting water from the sump. Such a pump is simple and reliable and requires little or no attention in operation, no lubrication, and the power for its operation can be obtained from the public water supply. For this reason it is particularly adapted to use in small buildings where the mechanical equipment must be of the simplest kind and where the cost of water is low. The capacities of Penberthy hydraulic ejectors are given in Table 76.

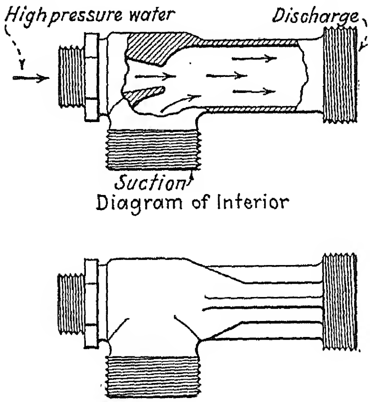

FIG. 118.—Hydraulic ejector. (*Penberthy Injector Co.*)

TABLE 76.—CAPACITIES OF PENBERTHY HYDRAULIC EJECTORS

Size number		62	63	64	65	66	67	68
Water-supply inlet, inches		3/8	1/2	3/4	1	1 1/4	1 1/2	2
Suction pipe, inches		3/4	1	1 1/4	1 1/2	2	2 1/2	3
Discharge pipe, inches		3/4	1	1 1/4	1 1/2	2	2 1/2	3
Length, inches		5	6 3/4	8	9	10 1/2	11 1/2	13 1/4
Capacity gallons per hour	40 pound per square inch	500	900	1,500	2,100	3,000	4,200	6,000
	60 to 80 pound per square inch	750	1,100	2,000	3,400	4,500	6,000	9,000

Capacities are given with 10-ft. head and include the operating water. The ejector suction should not exceed 22 ft. The total lift, suction plus discharge, can be about 1 ft. for every 4 or 5 lb. of water pressure.

The discharge lift of the pump is limited to about 12 to 18 ft.; and the discharge line should be arranged to prevent the back flow of air. This can be done by submerging the end of the discharge pipe, or by other means. The operation of the pump

requires about 4 to 5 lb. per square inch pressure on the power water supply line for each foot of lift and about 1 gal. of supply water for each gallon of water discharged for lifts up to about 8 ft. In order to obtain the best efficiency it is recommended that the ejector be set so that all of the lift is in the suction pipe; none in the discharge pipe.

178. Ventilation of Closed Sumps.—In the construction of "closed" sumps or reservoirs for the reception of sewage or drainage, ventilation must be provided to avoid the development of back pressures. This is particularly essential when air-displacement pumps are used as there may be a discharge of sewage or drainage in the house-drainage pipes when the inlet valve to the sump is closed or submerged.

Each sump should be provided with a vent pipe connected to the highest practicable point in the tank, unless the tank is of the air-displacement type which requires a completely closed chamber. When the design of the receiving tank is such that the house drain entering the tank may be closed at any time, a vent pipe should be provided on the house drain as near as possible to, but below, the lowest fixture, soil, or waste-pipe connection. The size and terminal arrangements of the vent pipe should be in accord with the requirements for all vents stated in Sec. 135.

179. Rain-water Gutters and Leaders.—Rain-water gutters and leaders are provided to catch the rain water falling on roofs, the ground, or other catchment areas, and to conduct it to some point of discharge, usually the sewer. In districts where no other suitable source of water is available the rain is collected in a cistern. The leader may empty directly into the cistern, which will be provided with an overflow; or a valve, as shown in Fig. 7, may be used on the leader to divert any portion of the roof water that is not wanted, such as that from the first rush of a storm which is laden with dirt from the roof, or when the cistern is already filled with water.

180. Inside and Outside Leaders.—Whether the leader shall be placed inside or outside of the building, or whether the leader shall discharge into the house sewer or the house drain is a matter of judgment on the part of the designer. It is stated in the Hoover Report:

There are advantages in not admitting roof waters to an interior house-drainage system. If the city has a separate system of sewers—

that is, domestic sewage and rain water kept apart—the admission of roof water to the house sanitary sewer would not be allowed. If the city has the combined system, the storm water should be carried separately to the house sewer. There is a tendency to change from the combined to the separate system and if this were done the cost of alterations in the plumbing required to bring about the separation would be much greater if the roof water entered the house drain than if it entered the house sewer outside of the building.

The admission of roof water to a house drain increases the danger of back pressure near the base of the stack, this danger increasing rapidly with the rainfall.

181. Sizes of Gutters and Leaders.—The recommendations of the Hoover Report with regard to the sizes of gutters and leaders are as shown in Table 77.

TABLE 77.—SIZES OF GUTTERS AND LEADERS

Area of roof, square feet	Gutter, inches	Inside leader, inches
Up to 90	3	1½
91 to 270	4	2
271 to 810	4	2½
811 to 1,800	5	3
1,801 to 3,600	6	4
3,601 to 5,500	8	5
5,501 to 9,800	10	6

The above sizes of rain leaders are based on the diameter of circular rain leaders, and the sizes of gutters are based on semicircular sheet-metal gutters with the top dimension given. Other shapes should have the same sectional area. Outside leaders, to the frost line, should be one size larger than inside leaders as required in the table.

The following is quoted from recommendations of the Copper and Brass Research Association:[4]

It is obvious that more water will drop through a vertical pipe than through a horizontal trough of equal area. Therefore it might appear that the leader could well be much smaller than the gutter and take care of all the water flowing into a gutter. The problem would resolve itself into one of hydraulics were it not for practical considerations.

It is also good practice to make the leader the same size in its descending length as at the outlet, so that there may be no stoppage due to leaves or ice. These factors enter so acutely into the design that the

problem becomes one more practical than hydraulic, although the principles of hydraulics enter into it.

Practice for leader sizes vary with different authorities from 75 to 250 sq. ft. of roof surface to each square inch of leader cross-section. This variation is due, in part, to varying conditions of rainfall in different parts of the country. The maximum rate varies from 4.5 to 8.7 in. per hour. In short periods during thunder showers even heavier falls have been recorded.

It seems reasonable to base computations on a rate of 8 in. per hour. At this rate of fall the water to be handled for 1,000 sq. ft. of roof surface is 666.7 cu. ft. per hour, or 0.185 cu. ft. per second or 83 gal. per minute.

Gutters and leaders large enough to carry away this amount of water will insure a satisfactory system.

The first step in designing such a system is location of the leaders. 75 ft. is the maximum spacing recommended. This done the area drained per leader is computed and the area of the leaders determined. A safe rule is 150 sq. ft. of roof area to 1 sq. in. of leader area.

An application of this rule gives the following tabulation:

Type of leader	Area in square inches	Leader size, inches	Area of roof drained, square feet
Plain round	7.07	3	1,060
	12.57	4	1,885
	19.63	5	2,945
	28.27	6	4,240
Corrugated round	5.94	3	890
	11.04	4	1,660
	17.72	5	2,660
	25.97	6	3,895
Polygon octagonal	6.36	3	955
	11.30	4	1,695
	17.65	5	2,650
	25.40	6	3,810
Square corrugated	3.80	1¾ by 2¼,	570
	7.73	2⅜ by 3¼,	1,160
	11.70	2¼ by 4¼,	1,755
	18.75	3¾ by 5	2,820
Plain rectangular	3.94	1¾ by 2¼	590
	6.00	2 by 3	900
	8.00	2 by 4	1,200
	12.00	3 by 4	1,800
	20.00	4 by 5	3,000
	24.00	4 by 6	3,600

The above figures can be reduced or increased to meet local conditions where the intensity of rainfall is definitely known.

There are practical considerations to the problem. No leader should be less than 3 in. where there is a possibility of leaves, etc. passing into it; 2-in. leaders are often used for porches and decks, and are permissible if precaution is taken to safeguard the gutter outlet against stoppage. The size of gutters depends upon:

1. The number and spacing of the outlets.
2. The slope of the roof.
3. The style of gutter used.

Some gutters are not effective for their full depth and width. In proportioning gutters proper consideration of the available area is essential.

The best type of gutter has the minimum depth equal to half and the maximum depth not exceeding three-quarters of the width. Thus the width becomes the deciding factor in proportioning its size. There is no reason for a gutter deeper than three-quarters of the width except for ornamental purposes.

Assuming that this proportion is observed the gutter may be referred to by its width only.

A gutter smaller than 4 in. wide is to be avoided. In common practice 4-in. gutters are seldom used for they are difficult to solder and increase the labor cost. The gutter may be the same size as the leader it serves, but, of course, cannot be smaller.

Half-round gutters are most economical in material and insure a proper proportioning of width and depth.

Safe rules for determining the size of gutters are:

1. If spacing of leaders is 50 ft. or less, use a gutter the same size as the leader, but not less than 4-in.

2. If spacing of leaders is more than 50 ft., add 1 in. to the leader diameter for every 20 ft. (or fraction) additional spacing on peaked roofs.

3. For flat roofs add 1 in. to the leader size for every 30 ft. of additional gutter length.

For ordinary residence construction 3- or 4-in. round and 2- by 3-in. or 2- by 4-in. rectangular leaders will generally suffice; 5-in. half-round gutters meet practically every requirement.

In large building design, such as factories and offices, careful attention should be given to the design of the roof-drainage system.

A safe system to follow in mill building design is that of the American Bridge Company. Their specifications provide as follows:

Span of Roof	Gutters	Leaders
Up to 50 ft.	6 in.	4-in. every 40 ft.
50 to 70 ft.	7 in.	5-in. every 40 ft.
70 to 100 ft.	8 in.	5-in. every 40 ft.

Notes.—1. Round leaders should not be less than 3 in. in diameter.

2. Rectangular leaders should not be smaller than 1¾ by 2¼ in. (This is commonly called "2" sq. in.)

3. Gutters should not be less than 4 in. wide.

4. Gutters should have a fall of not less than 1 in. in 16 ft.

5. Scuppers should be provided for all roofs with a parapet wall built around them. This precaution prevents an overloading of the roof due to stoppage of the outlet.

6. All outlets should be provided with screens or strainers.

182. Materials for Gutters and Leaders.—Rain-water leaders are constructed of cast iron, wrought pipe, and sheet metal. Gutters are usually constructed of sheet metal. Cast-iron and

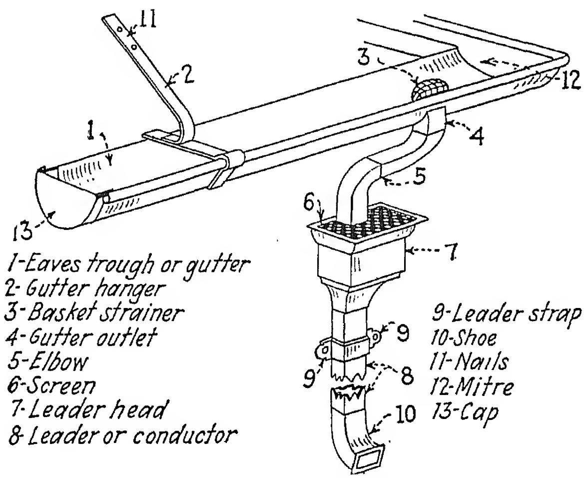

FIG. 119.—Roof gutter and rain-water leader.

galvanized wrought pipe are used for leaders within the building or in an inner or interior court or ventilating pipe shaft when these leaders are connected with the house drain or sewer. Outside leaders should be constructed of sheet metal with longitudinal corrugations rather than of cast iron or wrought pipe because the sheet metal is not so seriously affected by freezing and temperature changes. Cast iron is sometimes properly used for a short distance above the ground on account of the hard knocks to which this portion of the leaders may be subjected. The entire length of an outside leader should never be made of cast iron because of the damage from freezing, not only to the pipe itself but to the calked joints. The lead will be forced from

the joints by the alternate freezing and thawing of the wet oakum beneath it.

The method of the support of the gutter and leader and the connection between the gutter and the leader are important in their erection and maintenance. An installation illustrating good practice, and the names used for the parts of sheet-metal gutters and leaders, are shown in Fig. 119. The thickness of sheet metal which are recommended by different authorities for different purposes are given in Table 78. The recommendations of the Division of Simplified Practice of the U. S. Department of Commerce are:*

Plain round conductor pipe, 2, 3, 4, 5, and 6 in
Round corrugated conductor pipe, 2, 3, 4, 5, and 6 in.
Square corrugated conductor pipe, 2, 3, 4, and 5 in.
Eaves trough, 3½, 4, 5, 6, 7, and 8 in.
Conductor pipe elbows:

No. 1, 45 deg.
No. 2, 60 deg.
No. 3, 75 deg.
No. 4, 90 deg.

1. Along with the elimination of certain size of conductor pipe and eaves trough goes also that of the fittings formerly used therewith.
2. No eaves trough or conductor pipe to be made lighter than 28 gage full weight. Twenty-seven gage is to be eliminated.
3. All elbows, shoes, miters, and all accessories, including ridge rolls, valleys, gutters, and so on are to be of 28 gage full weight (0.0156 in. before galvanizing).
4. All eaves trough, conductor pipe, shoes, miters, and all accessories, including gutters, valleys, ridge rolls and so on, when made of copper, to be not lighter than 16 oz. per square foot (0.0216 in.).

The connection between the leader and the gutter should be made of brass, copper, or lead pipe and should be corrugated transversely so as to be flexible to allow for inevitable movements between the leader and the gutter. No. 19 B. and S. gage copper or brass pipe or extra light lead pipe should be used for the flexible connection. Similar corrugated flexible joints should be installed at intervals along the pipe so that there is at least one fold for each ¼ in. of movement of the pipe. In general one fold every 50 ft. with never less than two folds, is satisfactory. Outside leaders are subject to wide and rapid changes of temperature; the extreme range being sometimes greater than 125° F.

* Simplified Practice Recommendation 29, Approved Jan. 1, 1925.

The opening into the leader from the gutter should flare out at a small angle to twice the diameter of the leader and it should be covered by a screen to prevent the entrance of leaves, birds, and small animals. Provision should be made to permit water to overflow from the gutter, and to prevent accumulation on the roof, in case the leader becomes blocked.

The choice between copper and galvanized or painted iron gutters is a matter for the judgment of the designer who should consider the relative cost and durability of the two materials.

TABLE 78.—THICKNESS OF SHEET METAL FOR VARIOUS PURPOSES
(Thickness in inches)

Purpose	Galvanized iron	Copper or brass	Lead	Authority
Roof gutters....	0.016	0.0215[4]		[1] Dibble
		0.0156[5]		[2] Hoover
		0.040[2]		[3] Cosgrove
Outside leaders..	0.016	0.040[2]		[4] Copper and Brass Research Association
		0.0215[4]		
		0.0156[5]		[5] Division of Simplified Practice U. S. Department of Commerce
		0.064		
Flashing........	0.016	0.040[2]	0.135[1]	
		0.021[3,4]	0.101[3]	
Local vents.....	....	0.016		
Safes...........	....	....	0.101[2]	
Tank lining.....	....	0.016		

183. Traps and Connections in Rain-water Leaders.—Trapping of all rain water leaders connected to a house drain, house sewer, or other sanitary sewer is essential except where the leaders are made of cast iron, with calked joints, which terminate more than 12 ft. away from or 3 ft. above any opening into the building. Sheet-metal leaders connected to a sanitary sewer should always be trapped because of the possibility of the leakage of gas through the poorer joints and seams which exist in such pipes. The trap should have a large water capacity and a seal at least 4 in. deep and entire dependence should not be placed on rain water alone to maintain this seal because of the probability of the loss of seal

by evaporation during prolonged drought. Sand traps may be used on the leaders where no sanitary sewage passes through the trap. Fixtures discharging "clean water" without sewage, such as floor drains, ice-box drains, tank overflows, etc. should discharge through the trap on the rain-water leader to aid in maintaining the seal. Care should be taken to protect the trap against freezing by placing it within the building or by burying it below the frost line. Where the trap is buried, access to it should be provided to permit inspection and cleaning.

In order to prevent the overflow into a fixture no rain water leader should connect to a house drain above any fixture which is less than 5 ft. higher than the house drain. The connection between the house drain and the leader should be made by means of not less than one length of cast-iron pipe extending vertically at least 1 ft. above the grade line. Along driveways without sidewalks the leaders should be placed in niches in the walls, protected by wheel guards, or enter the building through the wall at a 45-deg. slope at least 12 ft. above grade.

184. Yard and Area Drains.—The principal purpose of yard and area drains is to carry off rain water as rapidly as it falls. All roofs and paved areas, yards, courts, and courtyards, should be drained into the storm-water sewer system or the combined sewer system but not into sewers intended for sanitary sewage only. When drains used for this purpose are connected with the combined sewer system, they should be effectually trapped, except roof leaders or conductors where the roof or gutter opening is located not less than 12 ft. away from or 3 ft. above the nearest door, window, scuttle, air shaft, or other opening into the building. One trap may serve for all such connections. All such traps should be set below the frost line or within the building. Where there is no sewer accessible the discharge may be into the public gutter, passing under the sidewalk, unless prohibited by local ordinance. Where the discharge is into the gutter it is not necessary to trap the rain-water leaders or other connections.

The capacity of the yard or area drain should depend on the rate of rainfall. An empirical rule, suggested in the Hoover Report, for estimating the rate of run-off is to consider the rate of rainfall as 4 in. per hour. This will give a rate of flow from each 100 sq. ft. of impervious area of, closely, 4 gal. per minute. In converting this into equivalent fixture units (see Sec. 128), 180 sq. ft. of drainage area is to be taken as equivalent to one fixture

unit. Having determined the rate of flow to be carried by the drain its size can be found in Table 56.

A catch basin should be placed at the inlet to the drain to prevent sand, cinders, and similar heavy material from entering the drain and the inlet to the catch basin should be protected by a heavy strainer to prevent the entrance of animals, leaves, sticks, and other large objects. The capacity of the inlet arrangement is as important as the determination of the capacity of the drain pipe as a mistake is sometimes made by using an inlet strainer of smaller capacity than the drain. Where no catch basin is used or where the catch basin outlet is not trapped and the drain pipe is connected to the house sewer, drain, or other sanitary sewer the yard drain should be trapped and access to the trap and the cleaning of the drain pipes should be provided for. The same care should be taken for preventing the freezing of and for maintaining the seal of this trap as is described for the seal of a rain-water leader in Sec. 183. A helpful arrangement in maintaining the seal is to connect the yard drain to the rain-water leader above the trap.

185. Subsoil Drains.—Subsoil drains are laid close to and outside of the foundations of a building to prevent water from entering the building. They may be laid somewhat as shown in Fig. 28 and at 58 in Fig. 109. They should consist of a 4-in., or larger, tile pipe, either glazed or porous, laid with open joints. Each piece of tile pipe is usually between 12 and 24 in. in length. By open-joints is meant that the pipe are all spigot end (no bells) and that when laid the ends are butted together or placed within ¼ in. of each other. The open joints thus formed should be wrapped in burlap or covered by broken tile, brick bats, or similar material to prevent the entrance of clay or sand, etc., when the trench is back filled. Sometimes vitrified-clay tile with bell-and-spigot ends are used because of their greater strength. The joints are made, however, without cement.

The pipe should be laid at about the elevation of the basement floor and within 1 or 2 ft. of the foundation wall. The pipe should be surrounded with gravel, or other loose material and the trench should be back filled with this or similar material to a depth of at least one foot and preferably more. The remainder of the trench to within a short distance of the ground surface should be filled with a porous material which will intercept any ground water and carry it to the drain tile. The drain may be

laid completely around the building or only on those sides from which ground water is expected. The drain is connected to the house sewer through a running trap and a vitrified Y connection, where no other point of discharge is possible.

186. Materials for House Drains and Sewers.—House drains when underground should be made of extra-heavy, cast-iron soil pipe with calked joints, although some codes permit the use of vitrified clay with calked joints under special conditions. The latter practice is not recommended, however, because of the poor workmanship usually secured in the making of the cement joints. House drains located above ground in the basement may be constructed of either cast-iron pipe or wrought pipe with cast-iron or drainage fittings or ordinary threaded fittings. House sewers are usually, and properly, constructed of vitrified-clay pipes with cement or poured joints or of Class A, or heavier, cast-iron pipe with calked joints. Where a sewer is laid at less distance than 5 ft. from the exterior wall of any building, or in bad ground, or on a poor foundation, or where it will be subjected to vibration, or to settlement, cast-iron pipe should be used. Where the ground is of sufficient solidity for a proper foundation or where special supports or a secure foundation are provided vitrified clay or cast-iron pipe should be used. The pipes should be laid in a trench with a smooth bottom with excavations for the bells or they should be so supported as not to bring any strain on the joints.

187. Harmful Waste in Sewers and Plumbing Systems.—Corrosive and harmful wastes and wastes at a temperature higher than about 140° F. should not be discharged into drainage pipes not specially designed to receive them. Under no circumstances should such wastes be discharged into plumbing systems to which ordinary domestic plumbing fixtures are connected because of the greater dangers when the seal of traps thereon become broken.

188. Installation of House Sewer.—When a public or private sewer is available every building near by should be independently connected to the sewer. It is sometimes permissible, when it is not otherwise possible to reach the common sewer where one building stands in the rear of another, to extend the house drain of the front building to connect with the house drain of the rear building.

All pipes when laid in the trench should rest directly upon firm undisturbed ground. They should not be laid upon back-filled material. Where it is desirable to place two pipes at different elevations in the same trench the side of the trench should be benched back at least 18 in. to receive the higher pipe. All pipes should be laid carefully in the trench in a straight line and on a smooth grade so as to facilitate cleaning and to avoid clogging. Where a deviation from a straight line is necessary it should be made with curves, Ys, or other suitable fittings so that the change of direction is not abrupt. Long radius curves can be made with straight pipe by placing each length slightly out of line at each connection.

A groove should be cut in the bottom of the trench for each hub in order to give the pipe a solid bearing for its entire length, and the soil should be well rammed on either side of the pipe. Joints in cast-iron pipe should be leaded and calked. The joints in vitrified-clay pipe should be cement, asphalt, or poured joints, as described in Secs. 146, 164, and 165.

The ends of all pipe not immediately connected to another pipe should be securely stopped by tile, brick, cement, or other water-tight and durable material.

Where the drains may be subjected to a back flow of sewage a back-water valve, or other device, should be installed to prevent the backing up of sewage or water into the building.

Whenever possible all house drains should be brought into the building below the cellar floor so as to insure drainage of the cellar floor and of fixtures placed in the cellar.

It is undesirable to run drains parallel to and less than 3 ft. from the bearing wall of a building. All drains and house sewers should be placed deep enough to be below the frost line. Where the elevation of the pipe at the house wall and at the public sewer connection, or other point in the line, are known the bottom of the ditch should be smoothed off parallel to a chalk line stretched tightly over it at any convenient distance above the two known elevations. Where a short line of sewer, such as a house sewer, is to be laid on a fixed slope the pipe can be laid to grade by constructing a straightedge from a plank about 12 ft. long, one side diverging from the other at the desired slope of the sewer. When this plank is rested on edge on the pipes in the trench the upper edge should be level if the sewer is laid to the right slope. It is not satisfactory to test the slope of individual lengths of

pipe because each length may have a satisfactory slope but the whole line may not.

189. Connection to Common Sewer.—Connections between house sewers and common or public sewers are made by means of Ys or slants previously installed, or by breaking through the existing sewer and inserting the desired connecting piece. All connections with any sewer 15 in. or smaller should be made through Y or T branches provided in the sewer for that purpose. Where such specials have not been provided, a Y fitting may be placed in the common sewer in the following manner:

A section of the pipe should be removed from the main sewer by breaking it to pieces, care being taken not to disturb the adjacent pipe. The Y fitting should then be inserted without chipping the pipe or branch, where possible; where not possible, the upper half of the bell on the run of the Y branch to be inserted, and the bell remaining on the main pipe and facing the opening should then be carefully removed and the Y branch inserted wrong side up, and revolved to bring the branch to the side for which it is intended, with the broken part of the bell up. The joint should then be cemented in the ordinary manner, the broken parts of the bells being well rounded over with a liberal amount of cement mortar.

190. Sizes of House Drains and Sewers.—The size of the house sewer should be the same or larger than the house drain; never smaller. No sewer should be smaller than 4 in. in diameter and preferably not less than 6 in. Where a larger house sewer is needed, its capacity must be estimated from the maximum rate of discharge from the house drain. With its capacity known the requisite size and slope of the sewer can be determined from Table 56 or the size can be determined on the basis of the total number of fixture units drained in accordance with Table 79.

TABLE 79.—SIZES OF HOUSE SEWERS

Fixture units	Sizes of house sewers in inches, sanitary system only		
	Slope in inches per foot		
	1/8	1/4	1/2
6 to 12	4	3	
13 to 24	4	4	3
25 to 72	6	5	4
73 to 300	8	6	5
301 to 720	8	8	6
721 to 1,080	10	10	8
1,081 to 1,920	12	12	10

The required size of storm-water drains and house sewers containing storm water should be determined on the basis of the total drained area in horizontal projection in accordance with Table 80.

TABLE 80.—SIZES OF HOUSE DRAIN AND SEWER FOR STORM WATER ONLY, DIAMETER IN INCHES

Area drained in square feet	Slope in inches per foot		
	1/8	1/4	1/2
Up to 90	1 1/2	1 1/2	1 1/2
91 to 400	3	2	2
401 to 660	3	3	2
661 to 1,200	4	3	3
1,201 to 1,800	4	4	3
1,801 to 2,500	5	4	4
2,501 to 4,100	5	5	4
4,101 to 4,600	6	5	5
4,601 to 5,300	6	6	5
5,301 to 7,500	8	6	6
7,501 to 11,100	8	8	6
11,101 to 15,700	10	8	8
15,701 to 19,500	10	10	8
19,501 to 24,800	12	10	8
24,801 to 31,000	12	12	10
31,001 to 44,000	14	12	10
44,001 to 60,000	14	14	12

All sewers and drains should slope at least 1/4 in. per foot and in no case less than 1/8 in. per foot.

Whenever a combined sewer system is employed, the required size of the house sewer should be determined by adding to the drained area in square feet, 180 sq. ft. for each fixture unit on the sanitary system, and then applying the total to the preceding table for storm sewers. No combined sanitary and storm sewer should be less than 4 in. in diameter. The required sizes of the sanitary house drain and the storm house drain, up to their point of junction, may be independently determined from the table.

References

1. Moffett, T.F "Roof Flashings for Plumbing Systems," *Plumbers Trade Jour.*, p. 630, Apr. 1, 1925.
2. "Roof Leader Design and Installation," *Plumbers Trade Jour.*, Vol. 76, p. 489, 1924; and Vol. 77, p. 204, 1924.
3. "Copper Flashings," 2nd. ed. 1925, The Copper and Brass Research Association.
4. *Ibid*, page 58.
5. Walker, J. R. "The Advantages of Inside Leaders against Outside Rain Leaders," *Trans. Am. Soc. Sanitary Eng.*, p. 24, 1925.

CHAPTER XII

THE PHYSICS OF PLUMBING SYSTEMS

191. The Value of Knowledge.—The physics of plumbing systems includes those subjects which are of importance in interpreting observations of various actions which take place in the pipes and appurtenances during the operation of the system. A conclusion drawn without full knowledge of related facts may explain the local action on a fixture or trap with apparent correctness but at the same time be erroneous and lead to dissatisfaction because of a lack of consideration of certain other factors not functioning at the time of observation. For example, it would be simple to draw a conclusion that a certain installed plumbing system is satisfactory because the trap seal was not broken on the lowest fixture when all of the higher ones were discharged simultaneously. The next day, however, a wad of cloth might be washed down with the discharge from a water closet and water would be blown from all of the fixtures on the lower floor. In the test the effect of solid matter mixed with the discharge was overlooked. A study of the physics of plumbing systems is helpful also in extending test data beyond the bounds to which the test observations have been limited.

192. The Effect of Solid Matter.—It is probable that the mixture of solid matter with the water flowing in plumbing systems will have a marked effect on the pressures produced. Since tests on plumbing systems are almost always made with clean water it is desirable to know the relation between the pressures created by clean water alone and by water in which solid matter is mixed. The type of solid matter to be used in tests should duplicate actual conditions as nearly as possible so as to give the most probable pressures. In the preliminary studies at the U. S. Bureau of Standards the solid matter used is described as follows:

To study the effect of introducing fecal matter and paper with the discharge from a water closet, pieces of thin-walled rubber tubing were filled with water and the ends tied and introduced with a quantity of

toilet paper. The use of such matter with the discharge from a single water closet produced measurable but erratic effects which became less noticeable with increased volume of discharge.

The type of solid matter used in the tests made at the University of Illinois is described as follows:

The solid matter used consisted of a wad of cotton waste which would just pass through the pipes. Each wad formed an almost air-tight piston which fitted the pipes so closely that it became stuck occasionally . . . The wads were inserted in the discharge pipe through a hand hole immediately below the fixture to be discharged . . . It is to be expected that such wads of solid matter would produce pressures much greater than those produced by water alone, and also greater than the pressures which would be produced by the ordinary mixtures of solid and liquid discharge from a water-closet.

It was noted that the wads of cotton waste materially increased the pressures produced at low rates of discharge but for large rates of discharge there was little, if any, appreciable effect. In discussing the observations it is stated;*

No effect was produced on the pressures in a 3-in. soil stack by the wad of cotton waste with discharges of more than 120 to 150 gal. per minute. It was noted that near the bottom of the stack the increase in the negative pressure was greater than the increase in the positive pressure and that the negative pressure appeared before the positive pressure. The positive pressure was not caused by the compression of the air ahead of the falling wad, as no positive pressure appeared until after the wad had been felt and heard to strike the bottom of the soil stack. The positive pressure developed suddenly, it was of short duration, and its intensity was determined apparently by the amount of resistance encountered by the solid matter in passing around the bend at the bottom of the soil stack.

193. Relation between Maximum and Average Pressures.—In making tests on plumbing the necessity for repeating the tests a very large number of times is to be emphasized because of the various results which will be obtained under apparently the same conditions. The observations are then averaged and the average pressure recorded as a measure of the phenomena observed. In plumbing design, however, the maximum pressure must be resisted by the seal of a trap and it is the maximum pressure which must be guarded against. It is not possible to

* *Bull.* 143 p. 52. Eng. Exp. Station Univ. of Illinois.

be assured that in any number of tests the maximum pressure or movement of water in the traps has been observed. In addition to this, the difficulty of making plumbing tests with wads of solid matter compared with those made with clean water alone makes desirable the determination of the relation between pressures made with and without solid matter, other conditions being equal. If a definite relation can be determined between the average and the maximum pressures observed in a series of tests, and the relation between the pressures produced with and without solid matter, the making of, and the interpretation of, plumbing tests will be greatly simplified. A determination of these relationships has been attempted by a study of the tests made at the University of Illinois. The following conclusions are stated on page 67 of *Bulletin* 143 of the Engineering Experiment Station:

a. For rates of flow equal to or greater than the simultaneous discharge of two or more water closets the ratio of maximum pressure with solid matter present to the average pressure without solid matter is in no case as great as two.

b. For rates of flow equal to or less than the discharge from one water closet falling 42 ft. down a 4-in. soil stack, the ratio of the maximum pressure with solid matter present to the average pressure without solid matter is greater than two, but the maximum pressure with solid matter present is only slightly greater than 2 in.*

c. For a rate of flow of 30 gal. per minute falling 42 ft. down a 3-in. soil stack the ratio of the maximum pressure with solid matter present to the average pressure without solid matter is about 4.5, and the maximum pressure with solid matter present is 0.33 ft. or 4 in.*

d. With solid matter present, the ratio of the maximum pressure to the average pressure is in no case greater than 2.5; without solid matter the ratio of the maximum pressure to the average pressure is in no case so great as 2.0.

194. Rate of Discharge and the Pressure Created.—Water passing through plumbing pipes will cause a pressure which will result in the movement of water in affected traps. If the rate of flow in the pipes is increased it is to be expected that the pressure will increase and, hence, the movement of the water in affected traps will increase. The question then arises: *What is the relation between the rate of flow and the pressure in a plumbing system?*

*Subsequent tests indicated that this intensity would be materially affected, and in most cases reduced, by the type of foot piece at the base of the stack.

Some results of tests made to answer this question are shown graphically in Fig. 120. These tests were made by discharging the equivalent of the simultaneous discharge of different numbers of fixtures on the same floor through stacks 42 ft. high and measuring the movement of water in vented or unvented traps connected directly to the stack. It was concluded, from these tests made at the University of Illinois, that the relation between

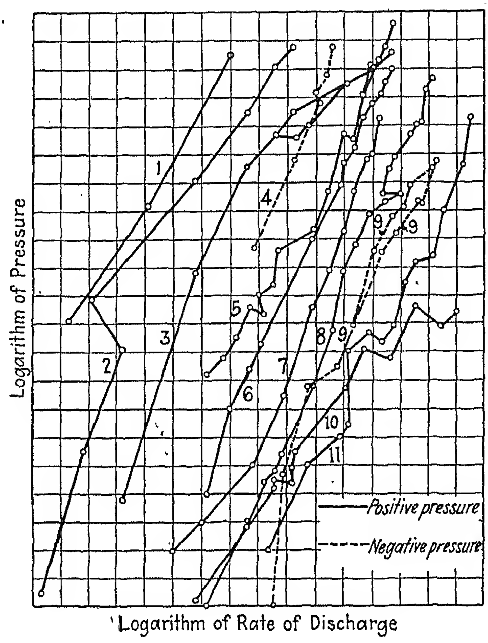

FIG. 120.—Pressures in a plumbing system and the rate of discharge down the soil stack. (*Bull.* 143, *Eng. Experiment Station, University of Illinois.*)

The traps in which the pressures were measured were not vented. The lines were placed to show slope only. Absolute values of the pressures and discharge are not shown and the scale is not the same for the different lines.

the rate of flow of water and the pressures created could be formulated. For unvented traps it was expressed as

$$P = kQ^{5/2}$$

in which P is the pressure created in the trap.

Q is the rate of discharge down the stack.

k is a constant dependent on the piping arrangement and the units in which P and Q are expressed.

For vented traps the relation was expressed as,

$$P = kQ^n,$$

in which the same nomenclature is used, and n is a constant depending on the type and capacity of the vent pipes. The values of n vary between about 0.33 when the crown of the trap is open the full diameter of the pipe, to 2.5 when there is no vent. With no vent the values of k varied between 0.00016 for discharges falling 42 ft. down a 2-in. stack and 0.00003 for the discharges falling the same distance down a 4-in. stack. In each instance the foot piece on the stack consisted of two 45-deg. ells connected by a short nipple and discharging into about 8 ft. of house drain of the same diameter as the stack.

There is no relation between the rate of flow through sloping pipes and the pressures in a plumbing system because the sloping pipes should be designed of sufficient size so that they will never be required to flow more than full, *i.e.*, under pressure. No pressures are, therefore, created by the flow of water in sloping pipes properly designed.

195. The Height of Fall of Water and the Resulting Pressures. When water falls in a vertical pipe, pressures different from atmospheric are created. If the lower end of the pipe is unobstructed and open to the atmosphere only siphonage is created.

If the lower end of the pipe is even slightly obstructed some back pressure as well as siphonage is created in the pipe. As the restriction to flow is increased the intensity of back pressure and the height along the pipe of the area in which the back pressure is felt is increased. Both siphonage and back pressure are increased as the height of fall of water is increased. The question then arises: *What is the relation between the height of fall of water and the pressures in a plumbing system?*

Some results of tests made to answer this question are shown graphically in Fig. 121. These tests were made by discharging water down a 4-in. stack 45 ft. high and measuring the pressures at different points along the stack and also by discharging water into the stack at different heights and measuring the pressures near the base of the stack. In all of the tests the connection at the base of the stack consisted of two 45-deg. ells joined by a short nipple. The stack discharged into about 8 ft. of 4-in. house drain.

It was concluded* that the back pressure created in unvented traps by water falling down a stack can be expressed as

$$P = kH^{5/4},$$

* *Bull.* 143, p. 32. Eng. Exp. Station, Univ. of Illinois.

in which P is the pressure, k is a constant dependent on the size and arrangement of the pipes, and H is the height of fall. The value of k is dependent also on the units in which P and H are expressed. No attempt was made to study siphonage or the effect of venting on this relationship.

196. The Effect of Wind.—The effect of wind blowing across the top of soil, waste, or vent stacks may result in the breakage or the weaking of trap seals. Tests made at the U. S. Bureau of Standards and reported in the Hoover Report* resulted in the following observations.

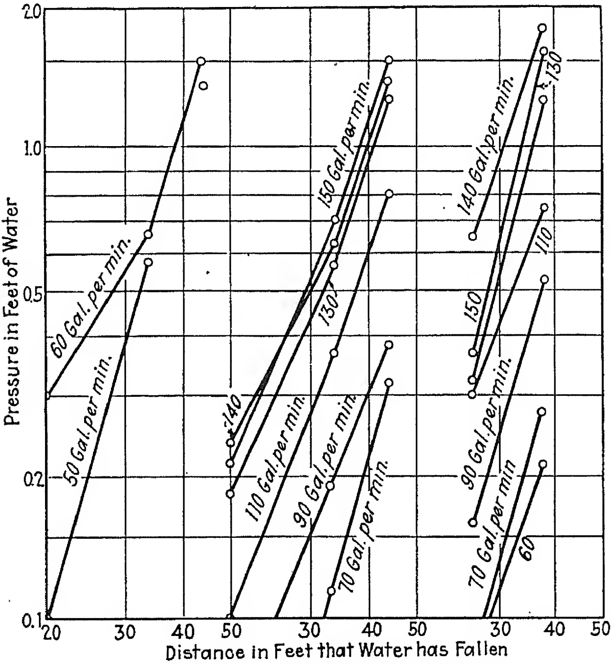

FIG. 121.—Positive pressures in a plumbing system observed in unvented traps and the height of fall of water in the soil stack.

With the system idle . . . and the end of the house drain open, the maximum effect obtained by a 45-mile per hour air current directed horizontally over the 3-in. stack top was a decrease in pressure in the system of 0.2 in. of water. With the end of the house drain submerged, giving a system closed at the lower end, a decrease in pressure of 0.36 in. of water was produced by a 45-mile per hour current directed hori-

* Page 128.

zontally; and 0.4 in. by a 45-mile per hour current directed upward at 30 deg. to the horizontal.

With fixtures on the system discharging, the wind effect was generally masked or shut off from unvented fixture branches below the point of discharge. In individually vented branches and unvented branches above the point of discharge the combined effect was the sum of the separate wind and fixture effects. In no case was a combined effect observed greater than that indicated by the additive relation.

In view of the small effects encountered it seems reasonable to assume that in small dwelling houses they will be taken care of by factors of safety referred to elsewhere.

A considerable degree of protection would be afforded in tall buildings or other buildings exposed to very high winds by running the vent stacks and soil stacks separately through the roof and connecting them together above the highest fixture, thus giving an opportunity for relief of pressure differences above the fixture connections. Then only when the effect was of the same kind and intensity over both stacks would the full intensity reach the fixture traps.

197. Closing the Top of the Stacks.—In the installation of a plumbing system the main stack and sometimes other stacks are carried through the roof and the tops are left open for purposes of ventilation. Various conditions may result in the clogging or the complete stoppage of these stacks. In cold climates the most common cause of stoppage is the formation of frost. Stoppages may result from other causes, such as the building of birds' nests, maliciousness, carelessness or ignorance on the part of persons dropping things down the stacks or laying things over the top of the stack. The question arises: *what is the effect on the pressures in a plumbing system of closing the tops of the stacks?*

Tests were made at the University of Illinois and The U. S. Bureau of Standards to answer this question. In the Illinois tests the top of the stack was sealed tightly and water was discharged into it at various rates and at different points. Observations of pressure were made at various points throughout the system. It is stated in the report:*

The pressures observed with the soil stack closed were much greater and the water in the observed traps oscillated more rapidly than when the soil stack was open at the top. The pressures in the traps changed rapidly from high positive to high negative pressure. In a number of tests the maximum pressure was four times the minimum. For rates of discharge greater than about 100 gal. per minute the stack shook with

* *Bull.* 143. Eng. Exp. Station. Univ. of Illinois.

the vibration caused by the recurrent vacuums and positive pressures and their sudden release. The oscillation of the water in the traps was so rapid that for the pressures greater than 0.5 to 0.7 ft. the reading could not be made closer than to the nearest one-tenth of a foot.

It is concluded as a result of the closure of the top of the stacks that: (*a*) both positive and negative pressures will be increased; (*b*) either positive or negative pressure, or both, will be created at points where caused by one or more water closets discharging down a 4-in., or smaller, soil stack, longer than 15 ft., when the top of the soil stack is closed is so great as to make probable the breaking of the seal of unvented traps connected to the soil stack or to pipes connected to the soil stack.

It is concluded that soil stacks should be designed so as to prevent the possibility of becoming stopped at the top.

The Hoover Report states as follows:*

Frost closure was simulated by setting sections of pipe of various diameter and length into the stack tops. No measurable effect was produced by setting a 1½-in. pipe 20 in. long into the tops of the 3-in. stacks of the different systems. A 1-in. pipe 12 in. long set in the 3-in. stack only slightly increased the vacuum produced by a heavy discharge from the fixtures. No doubt the effect would be felt more with an increase in the volume of the discharge. With a complete closure of the stack top the water was sucked from one or more traps by the discharge of a single water closet on the system. This occurs whether the traps are individually vented or not provided the stack tops are completely closed.

198. A Submerged House Drain or House Sewer.—It frequently happens in the operation of a plumbing system that the sewer into which the plumbing system is discharging becomes so filled that water is backed up into the house sewer or house drain. Under such conditions air entrained with the falling water must either be forced out through the backed-up water or must be separated from the discharging water. In either case relatively high pressures are to be expected.

The intensity of these pressures under some conditions have been measured in tests made at the University of Illinois and they have been found to fulfill expectations. Some results of the tests are shown in Fig. 122. It is concluded as a result of a study of the tests that:

A slight submergence of the outlet of the house drain or house sewer will result in a marked increase of both positive and negative pressures

* Page 129.

in unvented traps in the plumbing system and that a greater submergence will result in a further increase in pressure. If roof-water leaders are connected to the house drain and the flow is sufficient to overcharge the drain the condition may be expected to be the same as with a submerged outlet. It is concluded that the submergence of the outlet from a house-plumbing system should be avoided, but where unavoidable, the venting of the house drain or the house sewer at a point above the highest level of water backing up into the house drain or the house sewer will give relief.

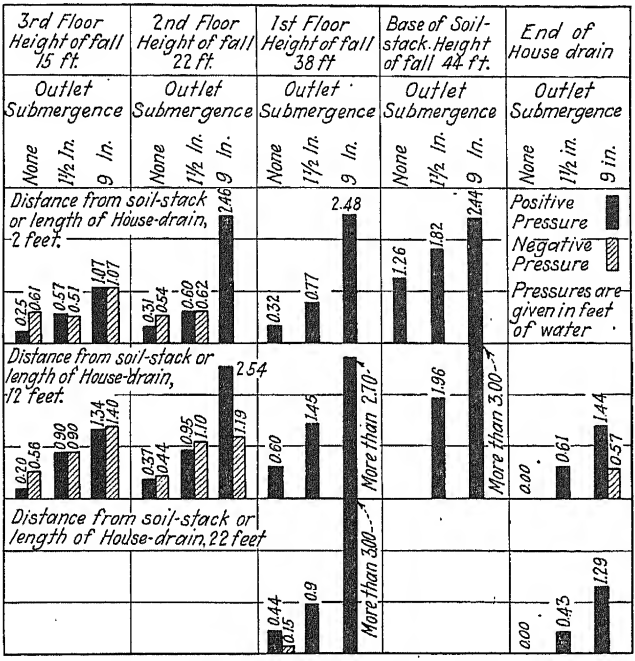

FIG. 122.—Pressures in a plumbing system with and without the end of the house drain submerged.

No house trap was used. The rate of discharge was 118 g.p.m.

Relief might be obtained also by the use of a by-pass vent.

199. Pressures Transmitted into Branch Pipes from the Stacks.—An important consideration in the design of a plumbing system is the proper distance to place a trap from a stack. Should it be placed far away or is it safe to place it close to the stack? Extensive tests were made at the University of Illinois in an attempt to find an answer to these questions. The tests

are reported in *Bulletin* 143 and in the October 1925 issue of the *Illinois Master Plumber*.

The transmittal of back pressure was studied by means of the piping arrangement illustrated in Fig. 123, and for the transmittal of siphonage by the apparatus shown in Fig. 88. Back pressure was created by discharging water at various rates down the soil stack shown in Fig. 123. The movement of the

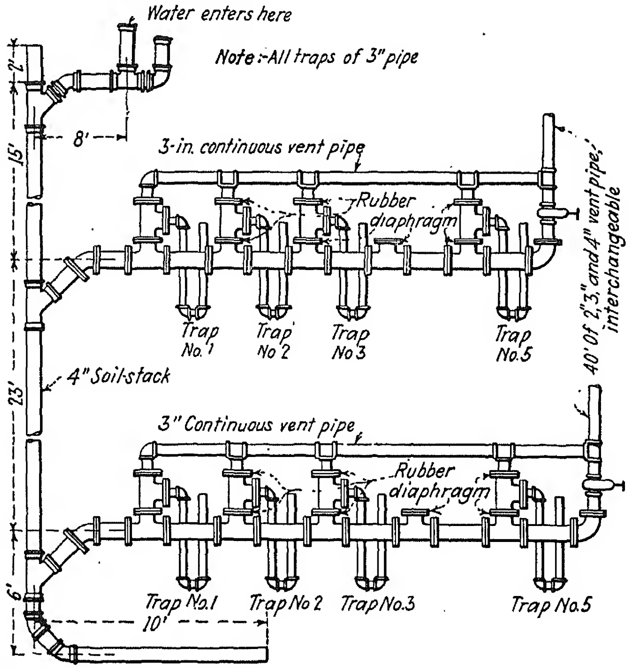

FIG. 123.—Apparatus used to determine the pressures at different distances from the soil stack and for various types of venting.

The traps were vented in various ways. The pressures were created by water falling down the soil stack.

water in the traps along the branch pipe was observed. The siphonage tests were made as described in Sec. 118. The intensity of vacuum was increased in successive trials until the seal of the trap was broken. Different lengths of waste pipe were tested. Some of the results of the tests are recorded in Tables 81 and 82.

The conclusions reached from these tests are brief and definite. They are that:

For lengths of horizontal (sloping) branch pipes up to 25 ft. the (back) pressure on all traps on the same (sloping branch) pipe is the same;

TABLE 81.—PRESSURES AT DIFFERENT DISTANCES FROM THE SOIL-STACK IN HORIZONTAL WASTE PIPES[1]

(The pressures are caused by discharges down the soil-stack, and are given in feet of water. The observations were made in the horizontal waste pipe at the lower level shown in Fig. 123 except as noted in the last line of the table.)

Type of venting	Rate of discharge, gallons per minute	Distance from the soil-stack to point where pressure was read in feet of water									
		5 ft.		10 ft.		15 ft.		20 ft.		25 ft.	
		Character of pressure									
		+	−	+	−	+	−	+	−	+	−
2-in. crown .	290	0.20	....	0.28	....	0.20	....	....	....	0.30	
3-in. crown .	290	0.15	....	....	....	0.15	....	....	....	0.18	
4-in. crown .	290	0.14	....	....	....	0.12	....	....	....	0.10	
2-in. loop...	290	0.14	....	0.36	....	0.26	....	0.29	....	0.17	
3-in. loop...	290	0.14	....	0.20	....	0.16	....	0.19	....	0.15	
4-in. loop...	290	0.13	....	0.12	....	0.10	....	0.13	....	0.10	
None.......	207	1.06	0.32	1.40	0.44	1.11	0.72	0.99	0.65	1.32	0.36
None.......	207	1.30	0.40	1.32	0.47	1.47	0.30	1.24	0.31		
None.......	207	1.18	....	1.37	....	1.26	....	1.12	....	1.32	
None[2]......	64	.03	.10	....	....	.02	0.12	0.06	0.13	0.04	0.18

[1] From *Bull.* 143, Eng. Exp. Sta., University of Illinois.

[2] The values in the last line of the table were observed at the upper level shown in Fig. 123, and the distances from the soil-stack to the points where the pressure was read were, respectively, 4 ft., 8 ft., 12 ft., 16 ft., and 20 ft

TABLE 82.—THE EFFECT ON THE PRESSURES IN A TRAP RESULTING FROM INCREASING THE LENGTH OF THE 1½-IN. BRANCH WASTE PIPE

Length of branch waste, inches	5	6	10	16	23	56	143
Intensity of vacuum, applied to the end of the branch waste, which was required to break the trap seal. Feet of water...........................	0.79	0.78	0.81	0.84	0.84	0.84	0.84

provided the venting of the traps is the same and the pressure is created by a discharge down the soil stack. The length of the connection between a trap and the soil stack does not affect the (back) pressure on a trap within the limits stated.

As a result of the tests on the transmittal of siphonage it is concluded that:

The length of horizontal waste pipe between an unvented trap and a stack does not, practically, affect the pressures which are transmitted to the trap.

A consideration of the conditions under which pressure is transmitted will emphasize the logic and the accuracy of these conclusions. The air held in the branch pipe between the stack and the trap must be considered as a solid elastic piston. The space occupied by it is not a reservior into which compressed air is driven from the stack or from which rarefied air is drawn into the stack. The wave of pressure is transmitted to the trap from the stack as sound is carried through air or as water hammer is transmitted through water. The rapidity of transmission of the wave of compression is dependent on the elasticity of the air rather than on its compressibility. The air through which the pressure is transmitted is not, itself, compressed. Hence the length of the column of air, that is, the length of the branch pipe, is of no practical importance in considering the intensity of pressures transmitted through a branch pipe.

No change in pressure of importance in plumbing design is affected in the transmittal of the pressure through a branch pipe from a stack to a trap and there is no practicable limit to the distance from a stack, along a branch pipe, at which a trap can be placed to avoid any pressure in the stack. The trap very close to the stack is affected no differently than the trap at some distance from it.

200. Pressures Transmitted in Branch Pipes from One Fixture to Another.—The pressures discussed in the preceding section are those created in a stack and transmitted through branch pipes to traps connected thereto. The intensities of pressure created in a branch pipe by the discharge of one or more fixtures are quite different than the intensities of pressures created in a stack by the discharge of the same fixtures. The intensity of pressure created in a branch pipe by the discharge

of one or more fixtures should be understood for the proper design of a plumbing system.

No pressures will be developed in branch pipes so long as the total rate of discharge into them is less than the capacity of the branch pipe, because, the pipes not being full, waves of air pressure find relief by passing through the branch pipe to the stack or vent pipe. When the discharge into a branch pipe exceeds the capacity of that pipe pressures are developed. The quality and intensity of these pressures depends so entirely on the piping layout that no general rules can be stated. Tests of the pressures developed in a few typical layouts will indicate the type and intensity of pressures which may be developed in other layouts.

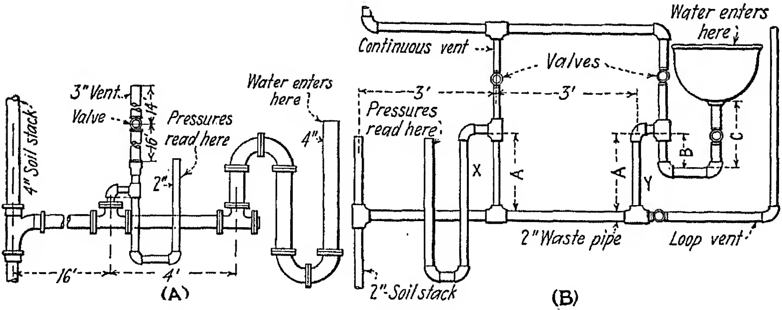

FIG. 124.—Apparatus for study of pressures transmitted in horizontal pipes. (*Bull.* 143, *Eng. Experiment Station, University of Illinois*, 1924.)

A. Apparatus used for study of pressures in a trap resulting from discharges into the 4-in. horizontal waste pipe to which the trap is connected.

The trap is located between the soil stack and the point of entrance of water to the waste pipe.

B. Apparatus used for study of pressures in a trap resulting from discharges into the 2-in. horizontal waste pipe to which the trap is connected.

Figure 124A shows one of the piping arrangements tested. Water was discharged into the 4-in. trap at the end, at the point marked, and pressures were observed in the 2-in. trap. The 2- and the 4-in. traps were interchanged and water again poured into the 4-in. trap with observations on the 2-in. trap. Another set-up of pipes for the study of this problem is shown in Fig. 124B. The position of the lavatory and the trap in which pressures were read were interchanged in different tests. Representative values of the pressures observed with these different arrangements of piping and points of entrance of water are given in *Bulletin* 143 of the Engineering Experiment Station at the University of Illinois.

The conclusions reached from a study of these tests are:

1. If two or more water closets can discharge simultaneously into the same 4-in. branch pipe, sloping ¼ in. per foot or less, all fixtures discharging into the same branch pipe below the second water closet must be adequately vented.

2. Where two or three water closets can discharge simultaneously into the same 4-in. branch pipe, sloping ¼ in. per foot or less, the upper end of the branch soil pipe should be vented.

3. Where four or more water closets can discharge simultaneously into the same 4-in. branch pipe, sloping ¼ in. per foot or less, all fixtures (water closets included) should be adequately vented which connect to the branch pipe in such a manner that a pair of water closets on each side of the fixture can discharge simultaneously.

4. Continuous venting is the best method of venting to control pressures created by the discharge of fixtures on the same horizontal branch pipe. Loop venting under such conditions is valueless.

5. Back pressure is produced in unvented traps only when the horizontal branch pipe runs full.

This was indicated by the tests in which a discharge at the rate of at least 100 gal. per minute for about 7 sec. into a 4-in. branch pipe sloping ¼ in. per foot was required to produce a positive pressure 4 ft. from the point of entrance of water into the branch pipe, measured towards the stack. A discharge at the rate of 18 gal. per minute for about 30 sec. into a 2-in. branch pipe on a slope of ¼ in. per foot produced positive pressures 3 ft. from the point of entrance of water into the branch pipe, measured towards the soil stack.

6. The back pressure produced by the discharge of other fixtures on the same horizontal waste pipe varies with the vertical distance of the discharging fixture above the waste pipe.

7. The pressures, both positive and negative, produced in an unvented trap at X, in Fig. 124B, with the fixture discharging at Y are the same as the pressures produced in an unvented trap at Y with the fixture discharging at X.

8. A continuous vent pipe, ¾-in. or larger, will prevent the development of undue pressures in traps arranged as shown in Fig. 124B, with the following limitations: (*a*) If the vent pipe is ¾ in. in diameter it must be less than 60 ft. long. It may be longer if the diameter is greater. (*b*) The rate of discharge must be less than 30 gal. per minute. (*c*) The waste pipe must be 2 in. in diameter or smaller.

9. The pressures created in a trap connected to a branch pipe, sloping ¼ in. per foot or less, by the discharge of a fixture connected to the same branch pipe will be less than the pressure created in the same trap by the same rate of discharge down a soil stack.

201. The Distance between a Trap and Its Vent.—In plumbing design the question may arise: "*What is a reasonably safe distance between a trap and its vent?* A consideration of the results of tests made to answer this question will give information as to the reasonableness and accuracy of such requirements, or where no code controls, will fix conditions for design.

Traps may lose their seal as the result of siphonage, self-siphonage, or back pressure. Siphonage and back pressure are created by the discharge of some other fixture on the plumbing system than the fixture whose trap is affected. The pressure must, therefore, be transmitted through the drainage pipes to

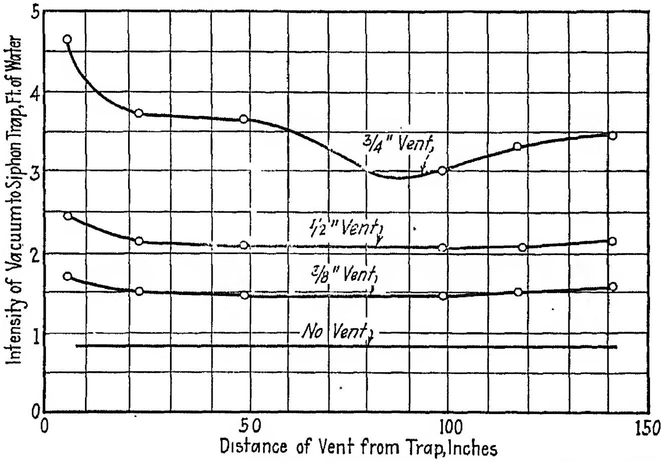

FIG. 125.—Tests on distance between a trap and its vent. (*From tests made in Eng. Experiment Station, University of Illinois.*)

the trap under observation. Self-siphonage is caused by the discharge of the fixture itself and the pressure (vacuum) is created within the trap and waste pipes themselves. Hence the location of the vent, to be effective in overcoming siphonage or back pressure might not be effective in overcoming self-siphonage, and a study of both conditions must be made to answer the italicized question. Such tests have been made at the University of Illinois.

In testing the transmittal of siphonage to a trap the apparatus used is shown in Fig. 88, except that the distance A was always 12 ft. 4 in. and six tees were inserted at various points along the branch waste pipe. The outlets to all but one tee were plugged during the test. The one open tee was used as a vent and ¾-,

½-, and ⅜-in. bushings were successively inserted in each tee. Some of the results of the tests are shown graphically in Fig. 125. It is concluded from these tests as follows:

(1) That a vent is most effective when placed close to the trap. (2) That the effectiveness of a vent in preventing siphonage or back-pressure (from being transmitted to the trap) is not seriously affected by placing it (the vent) as much as 12 ft. away from the trap, and (3) That the least effective location of a vent (to prevent siphonage or back pressure) is approximately half way between the trap and the stack (or other connection).

In studying the effectiveness of a vent in controlling self-siphonage the apparatus used is shown in Fig. 91. In performing these tests water was discharged at different rates from the fixture, variations were made in the drop, the length of waste pipe, in the sizes of the waste pipes, in the location of the vent, etc. An extensive series of observations was made. From the results it was concluded that the most effective location for a vent to minimize the effect of self-siphonage is as close as possible to the trap. Although a crown vent is shown to be more effective than any other type of vent its use in practice is usually prohibited because of its tendency to clog. The final conclusion is to the effect that where self-siphonage is to be overcome it is reasonably safe to place a vent 5 ft. away from the trap, provided such precautions are observed as are outlined in Sec. 133. Where siphonage or back pressure or both are expected it is reasonably safe to place a vent anywhere between the trap and the source of production of the abnormal pressure. In all cases, however, the most effective location for a vent is as close as possible to the trap.

202. Closed Chambers as Vents.—Closed air chambers are useful on water pipes to reduce the effects of water hammer. The transmission of air pressures in plumbing systems has been compared with the transmission of water-hammer pressure. Since the installation of air chambers would, in some cases, be less expensive than the installation of vent pipes it might prove economical to use air chambers. If this is so the question arises as to the proper capacity for the chamber under various conditions.

From a hypothetical consideration of the nature of the transmitted pressures, it would seem that air chambers would be of no value, because the transmitted pressures do not represent an expansion or

TABLE 83.—PRESSURES IN BRANCH PIPES, SLOPING 1/4 INCH PER FOOT[1]
(Pressures are shown in feet of water and represent the maximum of many observations)

Rate of discharge, g.p.m.	Type of vent: C = crown, L = loop, N = none, CC = closed chamber	Type of vent: Length of 3-in. vent, feet	Tests made with pipes arranged as shown in Fig. 124A, Pressure +	Tests made with pipes arranged as shown in Fig. 124A, Pressure −	Tests made with 2- and 4-in. trap interchanged but otherwise as shown in Fig. 124A, Pressure +	Tests made with 2- and 4-in. trap interchanged but otherwise as shown in Fig. 124A, Pressure −	Rate of discharge, g.p.m.	Type of vent: C, L, or N	Type of vent: Length of vent pipe, feet	Tests made with pipes arranged as shown in Fig. 124B, Pressure +	Tests made with pipes arranged as shown in Fig. 124B, Pressure −	Tests made with lavatory and observed trap interchanged but otherwise as shown in Fig. 124B, Pressure +	Tests made with lavatory and observed trap interchanged but otherwise as shown in Fig. 124B, Pressure −	
50	*L*	30	0	0	0.02	0.02	30	*C*	50	0	0	0.14	0.07	1
64	*L*	30	0	0	0.02	0.04	18	*C*	50	0	0	0.03	0.02	2
185	*L*	30	0.32	0.46	....	....	30	*L*	52	0.90	0.34	1.2	0.42	3
235	*L*	30	0.94	0.66	....	....	18	*L*	52	0.32	0.34	0.26	0.36	4
270	*L*	30	1.50	0.44	....	....	30	*C*	17	0	0	0.04	0.03	5
29	*C*	30	0	0.02	....	....	18	*C*	17	....	....	0	0	6
64	*C*	30	0	0.03	....	....	30	*L*	15½	0.84	0.40	....	....	7
185	*C*	30	0.04	0.04	....	....	18	*L*	15½	0.36	0.40	....	....	8
270	*C*	30	0.04	0.04	....	....	30	*N*	....	....	0.58	0.86	0.56	9
50	*CC*	16	0	0.34	....	....	18	*N*	....	....	0.55	....	....	10
65	*CC*	16	0	0.50	....	....	30	*C*	60*	....	....	0.06	0.13	11
185	*CC*	16	....	....	....	....	30	*L*	60*	0.82	0.40	....	....	12
64	*CC*	16	....	....	0.36	0.04	..	....	....	....	....	....	....	13
255	*CC*	16	....	....	0.01	0.02	..	...	....	....	....	....	....	14

[1] From *Bull.* 143, Eng. Exp. Sta., University of Illinois.

The following note refers to the conditions in Columns 8 to 14, inclusive:

The vent pipes were 1 in. in diameter except where marked * where they were 3/4 in. in diameter. The drop was 2 ft., the seal of the trap was 0.38 ft., and the length of the discharge pipe between the fixture and the trap was 1½ ft. The discharge from the fixture lasted from 6 to 12 sec. The waste pipe ran full and the trap seal did not break.

contraction of the entire volume of air in the pipes but rather a vibration such as occurs in the transmittal of sound. When the wave of water-hammer pressure reaches an air chamber its energy is dissipated into the air chamber. When a wave of pressure being transmitted through air in pipes reaches an air chamber the medium is unchanged and the pressure wave loses a negligible amount of energy in passing to the remotest corner of the air chamber and thence on to the other portions of the pipe. This hypothesis is borne out by tests as indicated by the results shown in Table 83. Here it is shown in the seventh, tenth, and eleventh lines of column 4 that the pressure in traps vented into a a closed air chamber is greater than that of a trap vented into a vent pipe under otherwise similar conditions. Although no extensive series of tests was conducted on this question, such evidence as is presented in this table together with the results of other tests and the corroboration of the hypothetical considerations leads to the conclusion that closed air chambers are of no practical value as vents for plumbing traps.

203. Self-siphonage.[1]—The factors affecting self-siphonage include; (*a*) the drop (see Fig. 91), (*b*) the depth of seal, (*c*) the

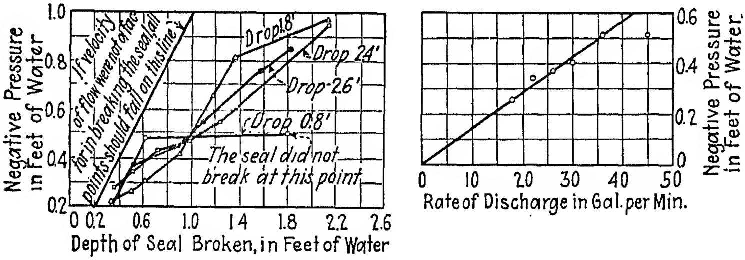

FIG. 126.—Self-siphonage tests on traps without vent. (*From Bull.* 143, *Eng. Experiment S.a.ion, Universi.y of Illinois.*)

rate of discharge, (*d*) the type of trap, (*e*) the type of fixture, (*f*) the size of the discharge (waste) pipe, and (*g*) the type and capacity of the vent pipes. In making tests to determine the relation between the factors affecting the breaking of the trap seal by self-siphonage it was found* that the shape of the fixture and the shape and condition of the trap were of great importance. When a vortex (whirlpool) is created as the water leaves the fixture, the trap seal seldom breaks. If the fixture is so shaped as to allow water to drop into the trap after the vacuum has

[1] See Sec. 119.

* *Bull.* 143, Exp. Sta. Univ. of Ill.

ceased to exist, the seal will be restored or strengthened. An irregular-shaped trap or one with rough surfaces which retards the flow of water reduces the intensity of vacuum produced.

The set-up used in making the tests at the University of Illinois is shown in Fig. 91. In making a test the trap and fixture were filled with water, the valve below the fixture was adjusted to give the desired rate of discharge, and then the plug was removed from the fixture. Observations were made of the intensity of vacuum created in the trap by reading the movement of the water in the manometer. A few of the many interesting observations made during these tests are shown graphically in Fig. 126, and in Table 84. The conclusions reached are that:

Table 84.—Observations in Tests on Self-siphonage
(From *Bull.* 143, Eng. Exp. Sta. University of Illinois)

Length of drop, feet	Depth of seal, feet	Rate of discharge, g.p.m.	Diameter of trap, inches	Material of trap	Intensity of vacuum, feet of water	Length of drop, feet	Depth of seal, feet	Rate of discharge, g.p.m.	Diameter of trap, inches	Material of trap	Intensity of vacuum, feet of water
0.00	0.33	....	....	Iron	[1] and [2]						
0.25	0.56	....	....	Iron	[1] and [2]	0.76	1.82	18	¾	Glass	1.10[2]
0.50	0.78	....	....	Iron	[1] and [2]	0.98	1.82	18	¾	Glass	1.22[2]
0.75	1.01	....	....	Iron	[1] and [2]	1.32	1.82	18	¾	Glass	1.44[2]
1.00	1.24	....	....	Iron	[1] and [2]						
0.48	0.38	18	¾	Glass	0.20[2]						
0.92	0.38	18	¾	Glass	0.28[2]	1.25			2	Iron	1.32[2]
1.75	0.38	18	¾	Glass	0.38[2]	1.25	1.82	18	2	Iron	1.81*
5.5	0.38	18	¾	Glass	0.25[2]	1.25	1.82	18	2	Iron	0.13[2]†
5.5	0.38	22	¾	Glass	0.27[2]	1.25	1.82	18	2	Iron	0.15*†
5.5	0.38	36	¾	Glass	0.51[2]						
1.80	0.35	18	¾	Glass	0.44[2]						
1.80	0.73	18	¾	Glass	0.62[2]	0.81	0.17	18	1	Iron	0.28[2]‡
1.80	0.90	18	¾	Glass	0.84[2]	0.81	0.17	18	1	Iron	0.32[2]‡
1.80	1.14	18	¾	Glass	1.38[2]	0.81	0.17	18	1	Iron	0.27[2]‡
1.80	1.35	18	¾	Glass	1.62[2]	0.81	0.17	18	1	Iron	0.96[2]‡

[1] Seal of trap just strong enough not to break. Any smaller depth of seal would have broken.

[2] The discharge from the fixture was complete and undisturbed.

* The plug was inserted in the fixture when the discharge pipe was flowing full.

† A 1½-in. crown vent, 50 ft. long was used in these tests.

‡ In these four tests the friction in the trap was progressively increased by increasing the length of its lower portion. The following lengths were used, corresponding to the order given in the table: 0.08 ft.; 0.22, 0.42, and 1.85 ft.

1. The resistance to self-siphonage is increased by impeding the flow of water through the trap. This can be done by baffling the trap, causing vortices, roughening the sides of the trap, etc. All of these methods are undesirable from other viewpoints, however.

2. The resistance to self-siphonage varies directly with the depth of seal.

3. The intensity of vacuum varies directly with the rate of discharge.

4. The intensity of the vacuum varies directly with the length of the drop. Some negative pressure is produced with no drop in the waste pipe due to the velocity of water passing through the pipe.

5. If the plug is suddenly inserted in the fixture when the entire discharge pipe is flowing full a very high intensity of vacuum will be produced.

6. The destruction or dangerous weakening of the seal of a trap by self-siphonage can be prevented by venting.

7. The destruction or weakening of the seal of a trap will be prevented when the fixture is so constructed that after the main volume of discharge has passed water will drip into the trap to restore the full strength of the seal. This condition can be attained by the use of a fixture with a flat, or an approximately flat, bottom of 50 sq. in. or more in area.

The studies on self-siphonage which were made at the U. S. Bureau of Standards were made to cover the following problems:

1. To determine the effect on self-siphonage of the size of outlet orifice relative to the size of waste pipe. It was concluded that it was desirable to allow the tail piece of a fixture to be the nominal size smaller than the trap.

2. To determine the relative resistance to self-siphonage of unvented plain *P* traps of various seal depths. It was finally recommended that no seal less than 2 in. deep nor greater than 4 in. deep be used.

3. To determine the effect of length of unvented waste on self-siphonage. No conclusion.

4. To determine the effect of fall or inclination of waste on self-siphonage. No conclusion.

5. To determine the influence on self-siphonage of a 90-deg. elbow in a normally horizontal unvented waste. It was concluded that the elbow slightly reduces self-siphonage.

6. To determine the effect of fouled waste pipes on self-siphonage. It was concluded that the greater the fouling the greater the self-siphonage.

CHAPTER XIII

MATERIALS

204. Materials Commonly Used.—The materials most commonly used in plumbing systems include; cast iron which is used in different weights for water pipe, sewers, traps, vent, and soil pipes; wrought iron or steel which is used mainly for water and drainage pipes, particularly for drainage pipes in tall buildings. Cast iron, wrought iron and steel, and malleable iron are used for fittings for water, drainage, and vent pipes. Lead is used for water pipes, traps, branch waste pipes, and in sheet form for flashings and safe wastes. Lead is used also for making joints in cast-iron pipes and for wiping joints in lead pipes.

Brass and copper are used for water pipes, for flush pipes from tanks to fixtures, for traps, faucets, and in sheet form for safe wastes, flashings, drip pans, strainers, etc. Vitrified clay is used almost exclusively for sewer pipes. Zinc is used for galvanizing and in sheet form for flashing. Tin is used for lining iron pipes which are to be exposed to particularly corrosive water and it is used in sheet form for flashing. Tin, zinc, and lead are used for lining pipes to prevent corrosion. Tin is used when mixed with lead to make solder metal.

Rubber and asbestos are used for gaskets and for packing in valves and faucets. Vitreous ware, enameled iron, and slate are used for fixtures. Cement and sand are used for making joints in clay pipe. Wood, hard rubber, etc. are used for toilet seats.

Other materials are used to some slight extent in plumbing and some of the materials mentioned above are used for other purposes than those enumerated. Only the more commonly used materials and the more common uses have been listed.

205. Pipes.—Water pipes are made of cast iron, wrought metal, lead, brass, or copper. Occasionally zinc, tin, or lead are used for lining cast-iron or wrought pipe to prevent corrosion.

Drainage pipes are made of cast iron, wrought iron or steel, lead, brass, or copper, except that galvanized steel or wrought iron should not be used for underground soil pipe.

Vent pipes are made of the same materials as drainage pipes.

Sewer pipes are made of vitrified clay with cement or poured joints, or of cast iron with calked, poured, or cement joints.

206. Fittings.—Plain threaded fittings should be made of cast iron, malleable iron, brass, or copper. Drainage fittings which are of threaded construction should be made of cast iron, malleable iron, brass or copper with smooth interior waterway and the threads tapped out of solid metal. All cast-iron fittings used for the distribution of potable water should be galvanized. All malleable-iron fittings should be galvanized where used for permanent installation.

All fittings of iron, mild steel, brass, or copper should be of equal quality to the pipe of the same material, and they should have a thickness and weight corresponding to pipe of the same diameter. The minimum thickness of metal on threaded parts must not be less than the minimum thickness permissible on pipe of the same size.

207. Calking Ferrules.—Brass calking ferrules should be of the best quality red brass with weights and dimensions as given in Table 85.

TABLE 85.—WEIGHTS AND DIMENSIONS OF CALKING FERRULES

Pipe size, inches	Actual inside diameter, inches	Length, inches	Weight	
			Pounds	Ounces
2	2¼	4½	1	0
3	3¼	4½	1	12
4	4¼	4½	2	8

208. Soldering Nipples and Bushings.—Soldering nipples should be of brass, iron pipe size, or of heavy cast red brass not less than the weights given in Table 86.

TABLE 86.—WEIGHTS OF SOLDERING NIPPLES

Diameter, inches	Weight, ounces	Diameter, inches	Weight	
			Ounces	Pounds
1¼	6	2½	1	6
1½	8	3	2	0
2	14	4	3	8

Note: Soldering bushings should be of brass pipe, iron pipe size, or of heavy, cast, red brass.

TABLE 87.—STANDARDS FOR MATERIALS AND EQUIPMENT

Standard	Adopted by	Date of adoption or source
Cast-iron water pipe, bell and spigot.	American Waterworks Association	May 12, 1908
Cast-iron pipe, flanged ends, "American Standard."	American Society Mechanical Engineers and others	Mar. 20, 1914
Cast-iron water pipe, flanged ends, for waterworks.	American Waterworks Association	Jan. 1, 1914
Cast-iron threaded fittings......	Manufacturers	Trade catalogues
Cast-iron soil pipe and fittings, bell and spigot.	American Society Testing Materials	1918 A74–18
Cast-iron soil pipe fittings, bell and spigot, dimensions.......	Manufacturers	Trade catalogues
Cast-iron soil pipe fittings, threaded, dimensions.........	Manufacturers	Trade catalogues
Wrought-iron pipe............	American Society Testing Materials	1924 A72–24
Mild-steel pipe................	American Society Testing Materials	1924 A53–24
Wrought pipe and fittings......	National Tube Company, and others	Handbook "National" Pipe Standards
Malleable-iron fittings..........	Manufacturers	Trade catalogues
Pipe threads, "American Standard."	American Society Mechanical Engineers	1886
Metal and wire gages..........	Manufacturers	Trade catalogues
Copper pipe..................	American Society Testing Materials	1924 B42–24
Brass pipe....................	American Society Testing Materials	1924 B43–24
Brass pipe fittings.............	Manufacturers	Trade catalogues
Cold-water meters.............	American Waterworks Association	June 9, 1921 and May 24, 1923
Lead pipe....................	Manufacturers	Trade catalogues
Clay sewer pipe...............	American Society Testing Materials	1924 C13–24
Solder metal..................	American Society Testing Materials	1921 B32–21
Pressure filters................	American Society Mechanical Engineers	December, 1916
Wrought-iron pipe............	Division of Simplified Practice, U. S. Department of Commerce	Sept. 1, 1926
Vitreous china fixtures.........	Division of Simplified Practice, U. S. Department of Commerce	Oct. 1, 1926
Brass lavatory and sink traps...	Division of Simplified Practice, U. S. Department of Commerce	Aug. 6, 1924
Structural slate...............	Division of Simplified Practice, U. S. Department of Commerce	Aug. 1, 1924
Conductor pipe...............	Division of Simplified Practice, U. S. Department of Commerce	Jan. 1, 1925
Hot-water storage tanks........	Division of Simplified Practice, U. S. Department of Commerce	Dec. 31, 1924
Range boilers and expansion tanks.	Division of Simplified Practice, U. S. Department of Commerce	May 1, 1924

209. Standards.—In the design of a plumbing system knowledge of manufacturers' standards, available materials, suitability of materials, and trade customs is essential to economy and correct design. Such knowledge can be obtained by reference to printed standards and lists of materials. Extensive

experience and constant practice are necessary to retain such information in the memory. Memorizing of exact dimensions is not necessary but knowledge that standards do exist and the use of these standards are essential. For example, let it be supposed that in the computation of the requisite diameter of a water-supply pipe it is found that an internal diameter of 0.49 in. is required. It would be natural to specify a ½-in. pipe, but in Table 117, in which the standard sizes of wrought pipe are given, it is seen that a ⅜-in. pipe has an internal diameter of 0.493 in.

Many similar examples of the necessity for knowledge of standards can be cited. It is necessary to know also the purposes to which various fittings are adapted, their standard dimensions, and the manner of their installation. Various authorities which have prepared standards are listed in Table 87 and the standards are presented in Appendix I, together with some recommendations as to weights and qualities of materials to be used for specific purposes. The qualities of most of these materials, as used in practice, are specified in the Standard Specifications of The American Society for Testing Materials.

210. Utility of Various Materials.—The principal corrosive elements encountered by the pipe materials under normal circumstances include the following:

Cast Iron.—Soft waters containing carbon dioxide (CO_2), organic acids, and oxygen. Also electrolysis.

Steel and Wrought Iron.—Affected by the same things as cast iron and to a greater extent.

Zinc.—Is slightly affected by soft waters containing carbon dioxide and oxygen.

Lead.—Is slightly affected, but enough to be dangerous to health when used as a water-supply pipe, by weak humic acids and other organic acids; very soft water containing carbon dioxide, strong alkalis, cement, etc. Heat accelerates the action.

Brass, Copper, Tin, Bronze, and Vitrified Clay.—Not materially affected by any element normally encountered.

Some materials are suitable for use only for certain purposes and some materials are used exclusively for particular purposes. For example, vitrified clay is used almost exclusively for sewer pipes outside of a building; cast iron is used for water-supply pipes in the street and for drainage pipes within a building; brass and copper, when used, are most frequently used for hot-

water pipes, etc. James R. Walker,[2] as a result of the study of replies from 73 cities to a questionnaire, found the following preferences with regard to material for service pipes:[3] 15 cities prefer genuine wrought iron; 2 cities prefer steel; 7 cities prefer genuine wrought iron, cement lined; 9 cities prefer brass; 40 cities prefer lead.

A questionnaire sent out by the Research Committee of the American Society of Sanitary Engineers concerning proper materials to be used for pipes in contact with acid wastes resulted in[4] the findings that lead, cast iron, brass, and clay are all used for traps, horizontal pipe lines, and vertical pipe lines. The life of these materials is short, seldom more than 3 yr., although vertical pipe lines coated with coal tar have been known which endured for 18 yr. The materials used for the fixtures include alberene stone, enameled cast iron, porcelain, and plain cast iron. The stone seems to be the most satisfactory to the majority of users. Some use cast-iron sinks with lead lining.

In addition to a choice in the quality of material to be used for any particular purpose, existing standards permit also a choice in the strength or weight of various pipes and fittings. These choices are explained and discussed in the section devoted to the particular pipe or fitting in which a choice is available.

211. Metallic Corrosion.—The effect of the corrosion of metals is so important in the selection of materials to be used in plumbing installations that a thorough understanding of its causes should be possessed by the plumber. The corrosion of metals can be explained on the theory of electrolytic action, or by a theory of oxidation, or both. Each theory gives a satisfactory explanation and each leads to practical methods for overcoming corrosion. It is probable, therefore, that corrosion takes place under the action of both electricity and oxygen.

212. Electrolytic Theory of Corrosion.—In an explanation of the electrolytic theory of corrosion, it has been demonstrated that when certain substances known as electrolytes are dissolved in water the particles in solution break up into groups known as ions, each ion bearing an electrical charge. The total potential of the solution is unchanged and, hence, the total charges on the negatively charged ions equals the total charges on the positively charged ions. If an electrical current be passed through the solution of an electrolyte the positively charged ions will move towards the cathode and the negatively charged ions towards

the anode. The electrical charges on the ions will be liberated and the physical nature of the ions will be changed. For example, if salt ($NaCl$) is dissolved in water and an electric current is passed through the solution sodium ions will migrate towards the cathode and chlorine ions toward the anode. The liberation of the electrical charge from the chlorine ion will form free chlorine at the anode and sodium will be formed at the cathode.

It so happens that the process can be reversed in nature and when two substances of different electrical potential, that is, different solution pressures* are placed in an electrolyte and the substances are connected by an electrical conductor an electric current will be set up in the conductor and through the electrolyte. The anode becomes the material with the higher solution pressure. As a result its ions are driven into the solution. The charges on the ions in the electrolyte will neutralize the charges on the electrodes and an electric current will travel through the conductor between the two electrodes. This action will continue until the electric charges on the ions in the electrolyte have been neutralized. This is an explanation of what occurs in an ordinary electric cell. In this action the anode becomes corroded and may be entirely eaten away.

The corrosion of metal is the result of setting up an electrolytic action within the metal between minute impurities in the metal which bear a different potential towards each other. When these two differing electrical potentials are immersed in an electrolytic solution an electric current is set up within the metal and continues until the electrolyte is neutralized or the electrodes are changed into substances of the same electric potential. In nature the electrolyte is continually renewed and, hence, the corrosion of the metal is continuous. The rapidity of corrosion is dependent on the difference of potential between the parts of the metal and on the strength of the electrolyte to neutralize the electric charges delivered to it.

The rusting of iron and steel can be explained by this theory. Iron rust is a hydrated oxide of iron ($Fe_2O_3nH_2O$). It will form only in the presence of iron, oxygen, and water. The absence of any one of these will preclude the formation of rust. The oxy-

* The solution pressure of a substance is a measure of its tendency to drive ions into the solution of an electrolyte in which it is placed.

gen, dissolved in the water, and the water itself, form a weak electrolytic solution. Now if *pure* iron be introduced into the water, experiment has demonstrated that it will not rust. Ordinary wrought iron and steel contain many impurities. The less homogeneous the composition of the metal the greater the difference in electrical potential between spots on the surface, and hence the more rapid the formation of rust or the corrosion of the metal.

The various metals have been arranged in Table 88 in the order of their relative solution pressures. The position of those metals for which no value is given is only approximate. The values given represent the tendency to form the ion indicated. Those metals which are not followed by the symbol of an ion do not possess, to more than a small extent, the power to yield simple positive ions in solution.

The metals often used in plumbing are printed in capitals in Table 88. It is to be noted that zinc is the only metal possessing a higher solution pressure, or potential, than iron. It means that iron in contact with all metals below it in the scale is subject to destructive action by corrosion and the position of the metals in the scale demonstrates why galvanizing is successful in protecting iron from rust. The position of iron and lead in the scale will aid in explaining why iron pipes connected to lead pipes will corrode more rapidly at the junction than elsewhere.

Table 88.—Potential Series of the Metals

Metal	Ion	Potential in volts*	Metal	Ion	Potential in volts*	Metal	Ion	Potential in volts[1]*
Sodium	Na^{+}	.....	Cobalt	Co^{++}	−0.045	COPPER	Cu^{++}	−0.606
Calcium	Ca^{++}	.....	NICKLE	Ni^{++}	−0.049	Mercury	Hg^{+}	−1.027
Magnesium	Mg^{++}	.....	TIN	Sn^{++}	−0.085(?)	Silver	Ag^{+}	−1.048
Aluminum	Al^{+++}	.....	LEAD	Pb^{++}	−0.129	Palladium	Pd^{++}	
Manganese	Mn^{++}	.....	Hydrogen	H^{+}	−0.277	Platinum		
ZINC	Zn^{++}	0.493	Bismuth	Bi^{+++}	....	Gold		
Cadmium	Cd^{++}	0.143	Antimony					
IRON	Fe^{++}	0.063	Arsenic					

* As measured by the difference between any metal and a solution which contains its ions in equivalent concentration. *i.e.*, a concentration equal to the same number of electrical charges; *e.g.*, since the copper ion contains a double charge of electricity one-half an atomic weight of copper is equivalent to a whole atomic weight of any element whose ion carries but a single charge.

213. The Oxidation Theory of Corrosion.—The oxidation theory is explained by F. N. Speller and W. H. Walker[10] as follows:

> Iron has a perfectly definite tendency to dissolve in water with the separation of an equivalent amount of hydrogen. If there be no impurities of any kind in the water this solution proceeds to but a very slight extent. The surface of the iron becomes covered with a protecting layer of hydrogen and the action ceases. If free acid exists in the water this hydrogen may be thrown off in the shape of gas and the solution of the iron proceed with greater activity. On the other hand, if alkali, such as caustic soda, be added not only is the acid neutralized and this action prevented but the water itself is less active in its attack upon the iron.

Natural water is saturated with oxygen. The oxygen reacts on the hydrogen film on the iron and destroys it. More iron is dissolved in the form of ferrous hydroxide which is soluble in water. The oxygen in the water oxidizes this to ferric hydroxide ($Fe_2(OH)_3$), which is hydrated iron rust. This is insoluble and precipitates forming the well-known "red water" nuisance. It is evident, therefore, that the removal of the active oxygen from the water will overcome this cause of corrosion. The deactivation of water is described in Sec. 220.

The corrosiveness of water is measured, to some extent, by the amount of oxygen, carbonic acid, and probably other gases dissolved in the water. Since the solubility of gases in water is proportional to the pressure it is possible to have high concentrations of corrosive gases dissolved in water in pipe lines and the removal of dissolved gases is important in retarding corrosion.

214. Methods for Retarding Corrosion.—In the process of manufacture the ultimate corrosion of the metal can be retarded by increasing its homogeneity; by creating an outer layer of specially resistant material; or by forming alloys with low electrical potential. All methods of treating the metal to prevent corrosion can be classed under these three heads. Corrosion can also be retarded by precautions in the installation of the pipe; by the use of protective coatings applied after manufacture; or by treating the material flowing through the pipe.

215. Care in Manufacture.—"Black iron," a common form in which wrought pipe and malleable fittings are available, is the result of allowing the iron to oxidize while hot so as to form a scale of magnetic oxide (Fe_3O_4) on the surface of the iron. This

scale adheres strongly to the iron and serves as an excellent protection against corrosion. When the surface layer is broken, however, the corrosion of the iron beneath the scale is rapid, as the scale is much lower in electrical potential than the iron.

Iron is made more homogeneous in manufacture by the process of Spellerizing. This consists in kneading the hot iron like dough between rough rolls producing a more uniform material. The oxide adheres more strongly to this metal and the result is a relatively more resistant metal.

216. Coatings.—The number of coatings used for the protection of iron are many. Some of these coatings are specified in detail in the Standard Specifications in Appendix I. They include:* tar or asphaltic coatings; paint; tin, copper, and nickel plating; lacquering; and enameling. All of the coatings used have shown some success in the prevention of corrosion but the cost is an important item. The relative magnitude of the costs of coatings is approximately in the reverse order stated above.

Tar or asphaltic coatings are applied by dipping the cleaned metal in melted tar or asphaltic compound. The use of this coating is highly satisfactory as a protection, but where the pipes are exposed to view their appearance is unattractive. They can be painted successfully to overcome this objection.

Galvanizing consists in applying a zinc coating to the metal. This can be done by cleaning (pickling) the metal in acid and then dipping it in molten zinc; or the metal can be electroplated with zinc; or zinc can be applied by the Sheradizing process in which the hot iron is revolved in a drum containing zinc dust. The Sheradizing process produces the best results, since the threads on threaded pipe are still useful after Sheradizing, which is not always the case after galvanizing with other processes.

Paints, for the protection of metal against corrosion, should be made of a metallic pigment, usually zinc or lead, mixed with an oil, usually linseed, which will dry to form a thin veneer over the surface of the metal; the pores of the veneer being filled with the metallic pigment. Zinc is a particularly desirable pigment on account of its electrolytic relation to iron. Varnishes and lacquers form a japanned or enameled surface which may be allowed to dry cold or may be baked on. Such coatings are pleasing in appearance but are usually easily broken. Aluminum, bronze, and gilt paints, particularly the former, are successful as

* Stated in the approximate order of the relative frequency of their use.

protective coatings but they are relatively expensive. Their appearance is sufficiently attractive to result in their frequent use.

Tin or lead plating or coating is applied in a similar manner to the hot-dip process of galvanizing except that the iron is passed through rolls at the same time that it is in the bath of molten tin or lead. The use of tin- and lead-lined pipes is satisfactory for all purposes, except that lead should not be used for the conveyance of drinking water. Sufficient lead may be dissolved, particularly when in contact with pure, soft waters, to be injurious to the health of the consumer.

Nickel and copper plating are usually applied electrolytically to the cleaned metal. Nickel, copper, and tinned coatings are valuable in the protection of iron because of their relatively low solution pressures. When the coating is once broken, however, galvanic action is set up between them and the iron resulting in more rapid corrosion of the iron. Zinc is, therefore, the best protective metallic coating, because as long as there is any zinc present it will corrode and protect the iron.

Vitreous coatings for metal are prepared by running a molten silicate into cold water. The resulting material is ground in a pug mill with clay and water. When worked up to the required consistency the metal is coated with it by dipping or brushing and when dry it is baked on to the metal.

217. Alloys.—Alloys of iron or steel with copper, nickel, or chromium are more resistant to corrosion than iron or steel alone. Such alloys are not often used in plumbing materials, however, because of their cost in comparison with other successful protective methods. Special processes for the development of rustless metal are successful and pipes and fittings of such material are available. These include the Bower-Barff rustless iron, Kalamein pipe, and Durion.

218. Resistant Materials.—For conveying acids or other highly corrosive material, cement-lined, glass-lined (vitreous) and rubber-lined pipe, tarred extra-heavy cast iron, cast iron enameled inside, vitrified tile, chemically pure lead, fibre, and other materials are used with success. Uncoated cast-iron pipe is not suitable for conveying corrosive wastes, particularly wastes of an acid nature. High silica pipe is resistant to acids but is more susceptible to the action of alkalis, particularly soda wastes. Pipes and fittings of high silica iron are manufactured of the same styles and dimensions as standard cast-iron pipes. Rust joints

instead of lead joints are more commonly used in this kind of pipe. A fibre pipe is manufactured which is resistant to both acids and alkalis but it is structurally weak and its use is confined to drain pipes under chemical laboratory sinks or similar locations. Some plumbing codes require the neutralization of acid in lime tanks before it is discharged into the sewer.

219. Installations to Avoid Corrosion.—Pipe should be installed so as to avoid corrosive substances or conditions, for example, wrought pipe, particularly when carrying steam or hot water, should not be placed in ashes which are occasionally wet, it should not be placed below a cinder-concrete floor. No pipe should be exposed to electrolysis.

220. Deactivation of Water.—The corrosive qualities of water to be carried in a pipe can be diminished or removed by the process known as deactivation. The deactivation of water to remove active oxygen and other possibly corrosive elements is accomplished by passing the water, usually when hot, through a tank, known as the deactivator, containing iron filings. A deactivator is shown in Fig. 127. It requires practically no attention in its operation except for a renewal of the iron filings once in 2 or 3 years and its cost is so small that its installation in regions containing corrosive waters is decidedly economical. A somewhat similar effect to the deactivation of water can be obtained by boiling the water in a vacuum or an open tank, thus driving off the dissolved gases. This latter method is impracticable in most installations.

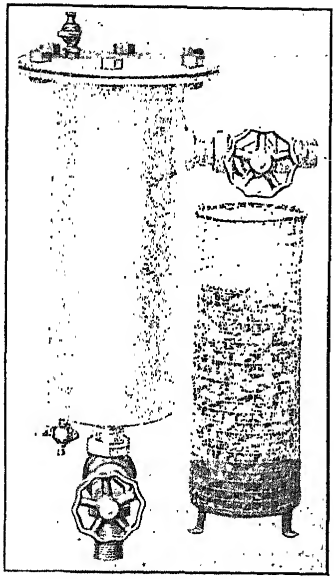

FIG. 127.—A deactivator.

221. Electrolysis.—Pipe lines buried in the ground are sometimes seriously damaged or destroyed by "electrolysis." Electrolysis is caused by direct electric currents, which have escaped from power lines, street cars, or other sources, attempting to return to the power house through the water pipes. So long as the water pipe furnishes a better conductor than the ground no

damage is done. But if the current leaves the pipe line, as it often does at joints, moist places, or for other reasons, damage is done where the current leaves the pipe.

Attempts have been made to overcome the effect of electrolysis by increasing the conductivity of the pipe by electrically bonding the joints. The pipes and the running rails of street car lines have been electrically connected and similar expedients have been attempted with indifferent success. The complete burial of the pipe in asphalt has given the greatest protection against electrolysis.

222. The Solubility of Metals in Water.—The solubility of metals in water is a consideration of importance primarily from the viewpoint of its effect on health and to a lesser extent upon the durability of the pipe. The solubility of the metals is dependent, to a great extent, upon the quality of the water. Pure water containing gases in solution, particularly oxygen and carbon dioxide, will dissolve metals more rapidly than hard waters already containing calcium and magnesium in solution. Not only is the solvent property of hard waters reduced but a scale is deposited on the walls of the pipe which retards solution of the metal. Surface waters containing organic acids also possess relatively high solvent properties. Because of the effect of materials already in solution in natural waters on the solution of metals it is not feasible to express, with accuracy, the solvent properties of natural potable waters on metals.

The metals most commonly used for conveying water are iron, copper, zinc, tin, and lead. The solution of iron in water has no deleterious effect on health. It does, however, have an effect on the durability of the metal. The presence of iron in water is undesirable because of its taste and the staining of clothing and plumbing fixtures. Iron is objectionable when present in a greater concentration than about 0.2 part per million.

The solubility of tin in water is so slight as to be negligible from the viewpoint of either health or durability and for this reason tin is used for conveying and storing water which is sometimes either highly solvent or which may stand in contact with the metal for long periods.

Copper is sometimes slightly solvent in water. It has been found in waters flowing through brass pipe in a concentration of 0.2 to 0.3 part per million, although such concentrations are unusually high. In this concentration it is not dangerous to health.

Zinc is sufficiently soluble to have a slightly injurious effect on health under unusual circumstances. It can be dissolved from galvanized coatings, from brass, from paint, or from the pure metal. It has been found in concentrations as high as 8 to 9 parts per million; the concentration after standing in galvanized or brass pipe being materially increased.[11]

Lead is sufficiently soluble in water to offer a real menace to health and for this reason its use in contact with potable water should be restricted if not prohibited. Tests by the Massachusetts State Board of Health have shown lead content as high as 3 to 5 parts per million in natural waters and an increase of 50 to 100 per cent, and even more, after the water has been standing in lead pipe. Since 0.5 part per million is considered dangerous to health, the use of lead in water pipe or in contact with potable water should be prohibited. Neither lead nor zinc paints should be used on surfaces in contact with potable water. Asphaltum, silicate, or enamel paints are preferable.

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CHAPTER XIV

DIMENSIONS AND TYPES OF PIPES AND FITTINGS

223. Cast-iron Water Pipe and Fittings.—Cast-iron water pipe is manufactured with either bell-and-spigot or flanged ends. It is manufactured in eight different standard weights, according to the standards of the American Waterworks Association. These classes are lettered from A to H, respectively. Class A, the lightest, is designed to resist an internal bursting pressure of 43 lb. per square inch; class H to resist an internal pressure of 347 lb. per square inch. The detailed weights and dimensions of these pipes and fittings are given in Section 1 of Appendix I. Two standard lengths are cast, 12 and 16 ft., in sizes from 4 to 84 in. in diameter. The 16-ft. lengths are most suitable for use on long pipe lines where it is desired to cut down on the number of joints to be made. They are not suitable for short pipe lines nor for work within a building because of their unwieldy length and the special care necessary for handling them.

Pipes with bell-and-spigot ends are used primarily as water mains in the street and for rough work within a building. Flanged or screwed ends are useful in interior work where space is limited and a neat appearance is desired. Flanged or threaded fittings are more expensive than bell-and-spigot fittings, they require more accurate cutting and fitting, and they lack the adaptability of bell-and-spigot pipe to slight changes in dimension or direction which are frequently met in installation. When properly fitted, however, they are easier to handle than bell-and-spigot pipe and they can be installed more quickly. Threaded-end cast-iron pipe is not generally manufactured but threaded cast-iron fittings for wrought-iron pipe are generally available. Dimensions of such fittings are given in Sec. 4, of Appendix I.

The use of any fittings other than standard is costly and time consuming. Their use should be avoided for these reasons and ingenuity exercised in the selection of standard fittings for the installation being designed.

224. Cast-iron Soil Pipe and Fittings.—Cast-iron pipe which is manufactured primarily for use as drainage pipe in plumbing

systems is lighter than cast-iron water pipe. It is generally known as "soil" pipe. This use of the term should not be confused with its use to designate any pipe which is carrying human wastes.

Two weights of soil pipe are manufactured; standard and extra heavy, the weights and dimensions of which are given in Sec. 5, of Appendix I. The choice between standard and extra heavy pipe is a matter of judgment. Categorical recommendations cannot be made. Where a first-class permanent job is desired; where the building is subject to vibration or settling; or where corrosive materials may be expected, extra heavy pipe should be used. In temporary locations or unusual conditions where a high standard of work is not desired standard pipe may be used. Extra heavy pipe should be used for house drains and house sewers where cast-iron pipe is to be used. Where the pipes pass through foundation walls or where they are subjected to high external loads, cast-iron water pipe should be used.

Cast-iron soil pipe is used for practically all drainage pipes 2 in. or larger in diameter in roughing-in work for stacks and branches except that for buildings more than about eight stories in height wrought pipe is often used.

Cast-iron fittings with either bell-and-spigot or threaded ends or a combination of such ends are manufactured for soil pipe. The threaded ends are tapped with a standard thread to fit wrought-iron pipe. The use of bell-and-spigot ends is common in plumbing work. It does not require such accurate cutting and fitting as the use of threaded pipe and the pipes and fittings are relatively less expensive. More skill is required in making the joints, however. Threaded joints are neater in appearance and can be installed more quickly than bell-and-spigot joints.

Threaded cast-iron fittings, known as drainage fittings, are made with a shoulder and recess and are so tapped that the pipe screws up tightly to this shoulder thus making a continuous interior surface of the same capacity as the pipe. This type of fitting is known as a Durham fitting.[1]

Manufacturers' standards for cast-iron drainage fittings are given in Sec. 6, of Appendix I. No standard dimensions for ordinary soil pipe and fittings have been recognized by any of the larger technical societies and manufacturers' standards differ in detail between the various manufacturers. The dimensions given in Sec. 6, of Appendix I, have been taken from various

sources. They are suggestive only of the sizes which are available. For detailed information the manufacturer must be consulted.

The styles and types of commonly used cast-iron soil fittings, as illustrated in Sec. 6, of Appendix I, together with other fittings manufactured but not illustrated, are so many as to make possible, by the exercise of ingenuity, almost any desirable installation without the use of special fittings. The use of cast-iron fittings which are not generally manufactured is to be avoided because of the expense and time involved in obtaining them.

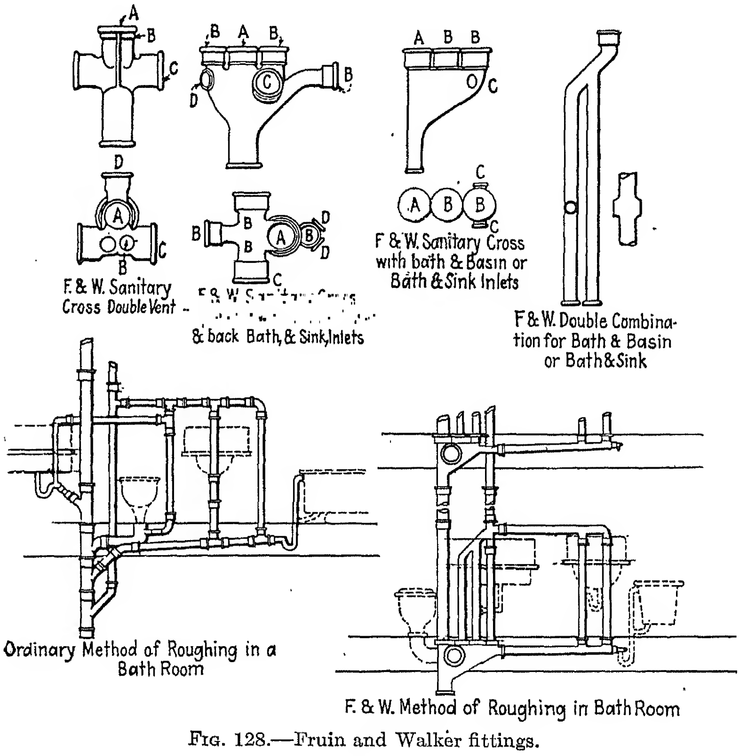

FIG. 128.—Fruin and Walker fittings.

225. Fruin and Walker Fittings.—The use of standard cast-iron soil fittings sometimes involves complicated installations which occur sufficiently frequently in practice to justify the manufacture of special fittings for such conditions. Some of these special fittings are patented. Among the better known and generally available fittings of this type is an extensive line known as F.

and W. (Fruin and Walker) fittings. One of the advantages claimed for these fittings is the infrequency of their clogging in practice. Rust and other foreign substances cannot lodge in them for as fast as it forms and falls in the vent pipe it drops on to the drainage part of the fitting and is swept away by the next rush of water. The fittings also displace two or more ordinary fittings, with their joints, thereby reducing the liability of leakage and, to some extent, the amount of work and material involved in the installation. An objection to their use is lack of general acquaintance with them and the special knowledge required for their use. A few of the F. and W. fittings and a typical installation are illustrated in Fig. 128.

226. Wrought Pipe and Fittings.—Standard specifications for the quality of wrought-iron and mild-steel pipe are given in Sec. 7, of Appendix I. The average quality of metal in welded tubular products is shown in Table 116.

In the manufacture of wrought iron,[2] pig iron is melted, in contact with slag which is mainly iron oxide, under the action of an oxidizing flame. The melted iron becomes more and more pasty as it is stirred or puddled in the furnace. When of the proper consistency the puddled ball is removed from the furnace and rolled. Wrought iron is also made from scrap iron consisting of materials of differing composition with a resulting wrought iron of decidedly inferior quality for use in the manufacture of pipe. The more uniform the material the less the tendency to corrode.

The puddled iron, as it comes from the furnace, is rolled into flat sheets with straight edges and of the thickness of the finished pipe. These flat plates are known as skelp. The skelp is cooled and sheared into lengths of about 18 ft. The processes of manufacturing butt or lap-welded pipe differ but slightly. The butt-weld process is used for the smaller sizes of pipe, the lap-weld, being stronger, is used for larger sizes. After the preparation of the edges, which are to come into contact, the skelp is heated to a welding temperature and pulled through dies which bend it to a circular shape and weld it in one operation. It is then sent through three series of rollers to get its final size, straightened, tested, and inspected. It is then in the form known as black iron pipe in which it should never be used except in temporary installations on account of the rapidity of corrosion. The various types of coatings to be used to protect pipe against corrosion are discussed in Sec. 216.

Since the method of manufacture and the materials in wrought-iron and steel are very similar, and good quality puddled steel has better lasting qualities than inferior wrought iron and there is difficulty in distinguishing between wrought iron and steel by appearance alone, there is much confusion in the trade between wrought-iron and steel pipe and much difference of opinion concerning the relative qualities of the two materials. The standard dimensions of pipes made from the two materials are the same so that in plumbing installations wrought-iron and steel pipes are used interchangeably and they are usually known as wrought pipe.

Wrought pipe with threaded ends has many advantages over cast-iron pipe except in first cost. Among the advantages are: fewer joints per unit length; the joints are tighter and stronger, and the alignment of the pipe is maintained better; flanged joints can be used to connect to lead pipe by bossing out the lead as a gasket between two flanges; etc. The joints are not affected by expansion and contraction, as are leaded joints in cast-iron pipe; the pipe can be cut to exact length in the shop with full confidence that it will fit on the job; with up-to-date cutting tools the pipe can be cut and fitted more rapidly and with less labor than with bell-and-spigot pipe; it can be installed further in advance in the construction of a building; and it does not occupy so much room in floors and partitions. It is more expensive in first cost than cast-iron pipe and in drainage work it is customary to use recessed fittings, which are also more expensive.[3]

The standard dimensions of wrought pipe are shown in Table 117. Pipes larger than 12 in. are known by their outside diameter and all pipes of the same nominal size have the same outside diameter regardless of their thickness. In the trade, pipes which are within 5 per cent of the weights shown in Table 117 are known as *full-weight* pipes; pipes that vary more than 5 per cent are known as *merchant pipes*. Merchant pipes are lighter than full-weight pipe but seldom fall more than 8 per cent below full weight. They are sufficiently strong for most plumbing purposes.

Couplings and nipples are the only pipe fittings made of wrought iron or steel. Other iron fittings are made of cast iron or malleable iron. Various sizes and styles of wrought-iron or steel couplings and nipples are illustrated in Fig. 186. The threads on these fittings are commonly cut right handed, but fittings with either left-hand or right- and left-hand threads can be obtained. The use of right- and left-hand threads is explained

in Sec. 56. The unthreaded portion of a sleeve coupling, as shown in Fig. 186, protrudes over the threaded portion of the pipe which does not come into contact with the threads of the coupling. In this manner the weakest portion of the pipe is protected. The dimensions of wrought couplings are shown in Table 119. Extra heavy or hydraulic couplings and double extra heavy hydraulic couplings are available for use on extra heavy or double extra heavy pipe. Nipples are really short lengths of wrought pipe. They can be made any length from a "close" nipple, which has a length of twice the standard length of threads on a pipe, to the full length of a pipe. Manufacturers usually carry nipples in stock in lengths varying by 1/4 in. from 3 1/2 to 6 in., and by 1/2 in. from 6 to 12 in.

227. Malleable-iron Fittings.—The confusion in the trade between the terms wrought-iron and steel and the difficulties of distinguishing between the two materials includes also, but to a lesser degree, the term malleable iron. Malleable iron is used for the manufacture of fittings. It is not used for the manufacture of pipe.

Malleable iron is a cast iron of such quality that it has some slight toughness which permits its being bent or pounded to a slight extent. It cannot be forged and it can be broken by the blow of a hammer. In the manufacture of malleable-iron castings the first casting is made of white cast iron containing the ordinary impurities. The casting is then made malleable by prolonged annealing. Malleable cast iron is stronger than ordinary cast iron.

Manufacturers' standards for the types and dimensions of malleable iron fittings are given in Sec. 8, of Appendix I. These standards include all the types of fittings available in cast iron and in pipe unions of various kinds.

228. Brass and Copper Pipe and Fittings.—Brass and copper pipe and brass fittings are used to carry hot water or corrosive liquids; and on account of their greater durability, their more attractive appearance, and their greater smoothness. Brass or copper pipe should not be used for carrying alkaline liquids, as they are more readily soluble in alkaline solutions. Standard specifications for brass and copper tubing, of the American Society for Testing Materials are given in Appendix I, Secs. 10 and 11, together with manufacturers' standards of dimensions of pipes and brass fittings. The strength of standard and extra heavy

brass pipe corresponds with the strength of standard and extra heavy wrought pipe. Brass pipe is made either plain, polished, or nickel plated and of either hard, soft, or medium temper, the latter being the most suitable for plumbing work.

Brass fittings are made with either threaded or flanged ends and in two weights, standard and extra heavy. Standard fittings are designed for working pressures up to 125 lb. per square inch and extra heavy fittings for working pressures up to 250 lb. per square inch. Copper fittings are not manufactured. Fittings are threaded or flanges are drilled in accordance with iron-pipe standards as given in Secs. 160 and 161. Practically all of the types of fittings available in malleable iron or flanged cast iron are available in brass. Nickel-plated brass fittings are generally available, nickel plating seldom being used on metals other than brass. Nickel-plated fittings are used for appearance only as they have no other advantage over unplated brass. They have a disadvantage, however, that the plating sometimes wears off unevenly giving the fitting an untidy appearance. Brass fittings are manufactured of cast brass with resulting rough surfaces or they can be obtained with a polished surface. The polishing of the surface serves only to improve the appearance of the fitting.

229. Standard Pipe Threads.—The American or Briggs Standard for pipe threads was adopted by the American Society of Mechanical Engineers on Dec. 29, 1886.[7] It has been subse-

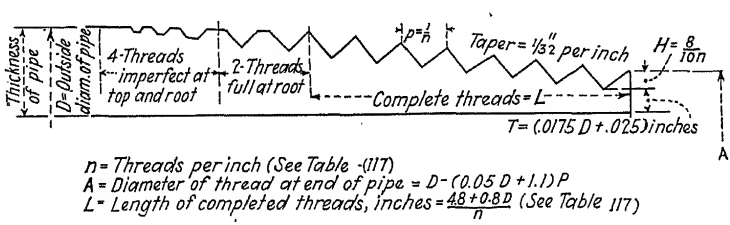

FIG. 129.—Standard pipe threads.

quently extended and revised by trade usage to conform to the conditions illustrated in Fig. 129 and stated in Table 117. The following conditions are standardized:

The depth of the thread $H = \frac{8}{10N}$; where N = the number of threads per inch.

The pitch of the threads increases roughly with the diameter.

The conically threaded ends of pipe are cut at a taper of ¾ in. diameter per foot of length, that is at a slope of 1 in 32 to the axis of the pipe.

The thread is perfect for a distance L from the end of the pipe. The value of L is

$$L = \frac{0.8D + 4.8}{N}$$

in which D = the outside diameter in inches. Then come two threads perfect at the root or bottom but imperfect at the top, and then come three or four threads imperfect at the top and bottom. These last do not enter into the joint at all but are incident to the process of cutting the threads.

The thickness of the pipe under the root of the thread at the end of the pipe equals:

$$T = 0.0175D + 0.025 \text{ in inches.}$$

In the threading of pipes or fittings it is important, to secure tight joints, that a sufficient length of thread be cut to make good contact and to develop the full strength of the pipe or fitting. The length of threads which should be in contact is given in Table 89.

TABLE 89.—LENGTH OF THREAD WHICH SHOULD BE IN CONTACT IN THREADED JOINTS

(See also Table 117)

Nominal pipe diameter, inches	Dimension, A, inches, Fig. 185	Nominal pipe diameter, inches	Dimension, A, inches, Fig. 185	Nominal pipe diameter, inches	Dimension, A, inches, Fig. 185
⅛	¼	1½	⅝	5	1³⁄₁₆
¼	⅜	2	¹¹⁄₁₆	6	1¼
⅜	⅜	2½	¹⁵⁄₁₆	7	1¼
½	½	3	1	8	1⁵⁄₁₆
¾	½	3½	1¹⁄₁₆	9	1⅜
1	⁹⁄₁₆	4	1¹⁄₁₆	10	1½
1¼	⅝	4½	1⅛	12	1⅝

230. Lead Pipe, Sheet Lead, and Solder.—Very little lead pipe is used in plumbing installations today and lead work is becoming less and less common. Among the advantageous features of lead pipe are its flexibility and durability. It will stand an almost unlimited amount of ordinary vibration without injury and it is practically non-corrodible by ordinary water

supplies or domestic sewage. The objections to its use include the cost, the skill required in its manipulation, and the dangers from lead poisoning. Lead is so flexible that if not well supported lead pipes will sag, producing pockets in which sediment may collect. It is claimed that rats will gnaw holes through it, and it is certain that workmen drive nails into it. In hot-water lines it may become softened sufficiently by heat to burst under pressure. Lead work in the making of joints is described in Sec. 163.

Lead pipe should not be used as a water-supply pipe for pure soft waters and its use to conduct any quality of water should be discouraged. Tests made by the Massachusetts State Board of Health have shown lead content as high as 3 to 5 parts per million in natural waters and an increase of 50 to 100 per cent, and even more, after the water has been standing in lead pipe. Since 0.5 part per million is considered dangerous to health the use of lead in water pipes should be prohibited.

The most common uses of lead pipe are as a flexible connection, called a "goose neck," between a water supply main in the street and a house service pipe; as a trap in the drain pipe from plumbing fixtures; as a flexible connection between a roof gutter and a rain leader; as a flexible connection between a water-closet seat and the cast-iron pipes of the plumbing system. Sheet lead is used for roof flashings and for drip pans or safes. Specifications for the composition of commercial lead products are given in Sec. 13, of Appendix I.

The various weights of lead pipe have received trade names, as listed in Table 127. The size of lead pipes is designated by the inside diameter. The following recommendations are made for the class of lead pipe to use for particular conditions:

For soil, waste, vent, or flush pipes, *light.*

Water supply pipes for normal pressure above ground, *strong.*

Water supply pipes for normal pressure under ground, *extra strong.*

Where unusually high internal pressures are to be carried the thickness of the lead pipe should be computed using the working strength of lead as 300 lb. per square inch in tension.

A typical lead goose neck and the manner of its installation are illustrated in Figs. 2 and 3, a lead connection between a roof gutter and a rain leader is shown in Fig. 119, and lead water-closet bends are shown in Fig. 136.

The recommended weights of sheet lead to be used for various purposes are shown in Table 78 and the weights of sheet lead of various thicknesses are given in Table 121.

The material of which solder is made is of such importance in securing success in joint wiping, lead, and sheet-metal work that the composition of solders should be thoroughly understood by the plumber. The Standard Specifications of the American Society for Testing Materials for Solder and Solder Materials are given in Sec. 15, of Appendix I. The composition of various kinds of solder are given in Table 73, and the fluxes to be used under various conditions are given in Table 74.

231. Vitrified-clay Pipe.—Vitrified-clay pipe is used principally for house sewers and to some extent for house drains. Its use above ground in the interior of buildings is commonly prohibited by plumbing codes and some codes prohibit its use anywhere within a building. The Hoover Committee Report states, on page 204:

> The use of vitrified-clay pipe should be prohibited for house drains . . . on the basis of history, experience, and weight of authority.

This does not settle the matter, however, as The Hoover Committee recommends further study of the subject. Vitrified-clay pipe is used extensively in English plumbing practice and their installations withstand the customary air and water tests probably because of the use of bituminous joints.

The prohibition of the use of vitrified-clay pipe within a building is caused by the difficulty of making and maintaining tight joints of cement. The brittleness and inflexibility of the pipe throws the strain of any movement into the joints. Where the joints are made of cement, cracking results from the slightest movement and the joint is no longer air tight. The model plumbing code of the Illinois State Department of Public Health permits the use of vitrified-clay pipe when underground within a building provided the joints are poured and tested.

Standard Specifications for clay tile and sewer pipe are given in Sec. 14, of Appendix I. In addition to the pipes of standard sizes and weights described in the Standard Specifications, double-strength pipe and pipe with extra wide and deep bells are used. The dimensions and weights of these pipes are also given in Sec. 14, of Appendix I. Extra heavy pipes are used where unusually heavy stresses are anticipated but the stresses are insufficiently

heavy to demand the use of cast-iron pipe. Deep and wide sockets are used for cement joints in wet trenches. 3-ft. lengths of pipe are preferable to shorter lengths as fewer joints are required.

The advantages in the use of vitrified clay are its durability, its low cost, and the simplicity of its installation. Clay pipe is unaffected by ordinary corrosive elements and many highly corrosive substances which may be found in sewage. It is not affected by many acids or alkalies. It is the cheapest material available, except possibly cement, for pipe of equal strength and carrying capacity, and it can be installed with success by unskilled workmen. An objection to the use of either clay or cement pipe within a building is the difficulty of securing a tight joint. This may allow the escape of sewage or sewer air, or may permit the inflow of ground water to overcharge the sewer, or it may permit the entrance of tree roots to clog the pipes. All of these objections can be overcome by the use of cast-iron pipe with leaded joints or by the use of poured joints in the clay pipe.

The use of cement pipe for such small sizes as are needed for ordinary house sewers is no more economical than vitrified clay pipe. Its use is not recommended, because cement is more susceptible to corrosion by acids and products of organic decomposition.

Methods for determining the proper sizes of sewer pipes are given in Sec. 190, and methods for the laying of vitrified clay pipe are described in Sec. 188.

232. Sheet Metal.—Sheet metal is used in plumbing for rain-water gutters and leaders, safes and safe wastes, flashings, roof extensions of vent pipes, and other purposes. It is also used in warm-air heating for furnace pipes and register bases, etc. The types of sheet metal available include: black iron, steel, galvanized iron, tin, zinc, copper, brass, lead, and aluminum. Table 121 and others give standard thicknesses and weights of these metals.

Black-iron or steel sheets consist of uncoated metal just as it comes from the rolls. It is seldom used in plumbing except for the most temporary installations. Brass and aluminum are seldom used in plumbing work on account of their cost and the suitability of less expensive metals. Galvanized iron, zinc, tin, and copper are the most commonly used sheet metals. Recommended weights and thicknesses of sheet metal to be used for different purposes are listed in Table 78. The methods of using

sheet metal are discussed in the sections devoted to the particular use to which the metal is to be put.

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CHAPTER XV

PLUMBING FIXTURES AND TOILET-ROOM EQUIPMENT

233. General Considerations.—Changes and advance in types and styles of plumbing fixtures have been so marked and rapid within the past few years, and promise to continue changing in the future, that any discussion of plumbing fixtures must be based on present-day requirements and customs, with the statement of a few fundamental considerations and a forecast of the future.

234. Requirements.—The fundamental requirements of all fixtures is that they shall be sanitary, economical, and pleasing to the user.[1] Sanitation is obtained by the use of non-absorbent, easily cleaned materials; by the proper location and maintenance of the fixture; and by the use of traps whose seals will not be broken. Economy is obtained through the production of durable fixtures at a low cost. The fixtures must be easily installed and the maintenance cost must be minimum. Satisfaction to the user is obtained through pleasing appearance, graceful lines, attractive colors, and comfort in use. The architect and the plumber must consider what might be termed the engineering or practical features of fixtures as well as the above-mentioned features which might be termed the esthetics of the fixtures. The engineering features include the rate of supply to and of discharge from the fixture, the type and number of fixtures required, the location of the fixture, together with other features pertinent only to certain installations and not of general importance.

235. Standard Dimensions.—The names of the various types of plumbing fixtures are listed in Tables 34 and 57, together with a statement of the proper size of water-supply pipe to and the discharge pipe from each fixture. No standard sizes of plumbing fixtures has, as yet, been adopted, although an attempt in that direction is being made by the Division of Simplified Practice of the U. S. Department of Commerce. Standard dimensions of water closets, flush tanks, and lavatories are shown in Figs. 191 to 196. The roughing-in dimensions must be secured from the manu-

facturer of the particular fixture which it is desired to install. A certain uniformity of practice is followed in some instances, however, which makes possible the drawing of plans and the layout of piping systems without knowledge of the exact fixture which is to be installed.

All fixtures, other than water closets, pedestal urinals, bidets, and fixtures of similar type should be provided with a strong metallic strainer with outlet areas not less than that of the interior of the trap or waste pipe. The overflow pipe from a fixture should be connected to the house or inlet side of the trap and it should be so arranged as to be easily cleaned.

236. Undesirable Types of Fixtures.—Fixed wooden wash trays or sinks should not be installed in any building. Copper-lined or sheet-metal-lined wooden fixtures are undesirable because of the vermin and filth which may lodge between the wood and the metal. Pan and valve plunger, offset washout, and other water closets having invisible seals or unventilated space or walls not thoroughly washed at each flush should not be used. Range closets are suitable only for temporary use as in a ball ground, fair ground, etc. Long hopper closets or similar appliances should be installed only in unheated places. No dry closet or chemical closet should be installed in a dwelling or other building when a common sewer is available.

237. Materials.—The materials used for plumbing fixtures include: vitrified porcelain, solid porcelain, enameled cast iron, black cast iron, tinned copper, galvanized iron, glass, soapstone, and marble. The first three materials named are used the most extensively. They include semi-vitreous ware and terra cotta. Proposed manufacturers' specifications for vitreous ware are given in Sec. 17, of Appendix I. Other materials are rarely used except for special services.

Vitrified porcelain is china but the trade name china is frequently applied to unvitrified glazed ware made from baked clays. Vitrified ware is the most expensive and the most attractive in appearance of the three commonly used materials. It cannot be used for heavy fixtures, such as bathtubs, urinals, etc. because the high temperature required for vitrification (2600° F.) causes warping in the kiln. It is successfully used for lavatories, bubbling fountains, and toilet seats, however. Solid porcelain is glazed only on the outside. It is not vitrified and, as a result, it will craze in time. Enameled cast iron is satis-

factory except that it is seriously affected by acids, even lemon and other citrous fruit juices staining it. Enameled-iron fixtures should always be made in one piece, as cracks in fixtures are difficult to keep clean. A standard test for vitreous china fixtures has been adopted by a manufacturer's committee cooperating with the Division of Simplified Practice of the U. S. Department of Commerce. The details of this test, together with definitions of trade terms, are given in Sec. 17, of Appendix I.

238. Supply and Discharge Rates.—The rate of supply of water to a fixture should be such as to fill the fixture within a reasonable time or to supply the demand for water to the satisfaction of the consumer. The factors entering into these considerations are so many that it is not possible to state definitely what should be the rate of supply to various fixtures. Just what is a reasonable time, or what will satisfy the consumer cannot be stated exactly because what may be reasonable or satisfactory to one will not be to another. In Table 35 some information is given as to proper rates of flow to provide to individual fixtures. Table 36 shows approximate rates of time to fill fixtures through different sized pipes, and Table 34 contains recommendations of pipe sizes to individual fixtures. The determination of the exact size of pipe to be used under the conditions to be met in any design is left to the judgment of the designer. Where the rate of loss of pressure in the service pipes is unknown it is suggested that the rate be assumed as $H = L$ in which H is the loss of head and L is the length of the pipe. The supply pipes should then be designed according to this assumption. If the supply pipes are already in place a study of the loss of pressure through them can be made by the method outlined in Sec. 38.

The results of many tests on the rates of discharge from fixtures are available. Among the most extensive and convincing tests are those reported by the Hoover Committee. The results of the Hoover Committee tests are summarized in Table 90.

Fixture discharges have been expressed in terms of fixture units. The fixture unit adopted by the Hoover Committee is a discharge of 7½ gal. per minute. As a result of the tests at the U. S. Bureau of Standards the Hoover Committee recommends that the discharge from different fixtures be expressed in fixture units, as stated in Sec. 128. The sizes of traps, branch wastes, and soil pipes for the fixtures, as recommended by the Hoover Report, are given in Sec. 129.

TABLE 90.—RATES OF DISCHARGE FROM PLUMBING FIXTURES
(Hoover Committee Report, p. 91)

Fixture	Outlet, nominal diameter, inches[1]	Trap and waste, inches	Rate, g.p.m.	Fixture units or cubic feet per minute	Velocity in drain, feet per second	Time to empty, seconds[2]
Basin	1¼	1¼	7.5	1	1.9+	12
Sink	1½	1½	11.3	1½	2.0	30
Bathtub	1½	1½	15.0	2	2.7+	90 to 120
Bathtub	2(3)	2	26.3	3½	2.0+	60 to 80
Laundry tray	1½	1½	22.5	3	4.0	20
Common fixture with one trap	1½	1½	22.5	3	4.0	20 and up for one. 40 for two
Water closets	3	3	45.1	6	2.0+	6 to 10

[1] Outlets from fixtures are commonly made one nominal size smaller than the trap for convenience in making slip-union joints a practice that offers other advantages. Hence the actual diameter is less than stated nominal values, varying from ⅛ to ¼ in.

[2] Time for emptying the basin and sink are given for the full fixture, 1½ and 6 gal., respectively. The time given for other fixtures gives a range that will vary with the capacity of the fixture and the extent of filling.

[3] No determinations were made with 2-in. bathtub outlets and the values given represent an estimate to the nearest one-half fixture unit.

239. Number of Fixtures Required.—In an ordinary residence the question of the number of fixtures needed is determined by the owner. He decides he wishes one or two or more bathrooms and each bathroom is equipped with a water closet, a lavatory, and such other fixtures as are desired. In schools, factories, public comfort stations, office buildings, hotels, and other buildings of a public or semi-public nature, the question of the number of fixtures to be installed is frequently left to the judgment of the designer. Only personal experience or knowledge of the experience of others can aid the judgment. The rules given in Table 91 show the requirements or customs of various state boards of health and others with regard to the number of fixtures of various types to be provided.

240. Number of Fixtures in Use Simultaneously.—The number of fixtures of the same type in use at the same time in toilet rooms in the same building has been the subject of intensive study by the Hoover Committee. These studies have been based on the mathematical theory of probability. The practical value of such a study is open to question, because the ideal condition in determining the proper number of fixtures to install in any

TABLE 91.—NUMBER OF FIXTURES REQUIRED[1]

Maximum number of persons to use one fixture				Remarks
Water closets		Urinal	Lavatory	
Male	Female			
20	20	40	...	One lavatory for every five fixtures (closets and urinals). Two feet of trough constitute one urinal for places of employment
500	200	300	...	Theaters and assembly halls
150	100	300	...	Dance halls
40	20	40	...	High schools, and higher grades
30	15	30	...	Grammar schools and lower grades
10	10	0	10	Dwellings, also one bathtub and one sink for each ten persons
				Apartments, one bathtub, one lavatory, one toilet for each apartment
300	150	150	...	Theaters, on stage, when stage is more than 300 sq. ft. there must be a separate water closet for each sex, and one drinking fountain. In auditorium one drinking fountain for 400 seats
300	150	150	...	Churches, one drinking fountain for 400 seats
25	15	15	100	Schools, one drinking fountain for 200 seats
100	50	100	...	Libraries, museums, etc.
50	40	50	...	Asylums and hospitals, one drinking fountain for 50 persons
				Penal institutions, one water closet and one lavatory in each cell
100	70	100	100	Clubs, lodges, etc., one drinking fountain to each 100 persons
30	20	20	20	Workshops, one drinking fountain for each 50 persons

[1] Data above the heavy horizontal line from Wisconsin State Plumbing Code. Data below the heavy horizontal line from W. C. Groeniger.

toilet room should be such that all fixtures are in use at one time with no person waiting. The impracticability of attaining such an ideal is apparent. In order to avoid waiting by anyone an excess of fixtures for normal demands must be installed. Even with all fixtures actually occupied the probability of their being flushed or emptied simultaneously is low. The value of a study of the number of fixtures in use at one time lies in the smaller water-supply, soil, and waste pipes which may be used. For instance, if ten water closets are installed on the same soil pipe and all are discharged simultaneously the rate of flow will be approximately 500 gal. per minute. Under conditions of normal flow this would call for a 10-in. branch soil pipe on a

slope of ¼ in. per foot. In Table 58, only a 6-in. pipe is called for. The reason for the use of the smaller pipe is based upon the improbability of the simultaneous discharge of the fixtures attached thereto. In this connection the Hoover Report states:

From the standpoint of economy in the installation of plumbing systems it is obviously desirable to secure a closer approximation of the peak load and the frequency of its occurrence based logically upon data representing the conditions involved. This can be done by determining the probability of coincident discharge of the various fixtures based upon the observed frequency of use, the duration of the individual discharge, and the predetermined rates of discharge of the various fixtures. The application of the method of probabilities to such a problem is not precise since it is based upon variable and somewhat indeterminate time factors. The results are, therefore, to be regarded as approximations and applicable to large systems more closely than to small ones. The method will, however, be found helpful in the analysis of small systems.

The results of a digest of the Hoover Committee studies are given in Table 92. The following is an illustrative example of the use of this table:

Example.—Let it be assumed that five water closets are to be installed in a toilet. How often will a branch soil pipe large enough to carry the simultaneous discharge from all five closets be filled to capacity or how often will a branch soil pipe large enough to carry the combined discharge from four closets be filled to capacity?

In Table 92 it is stated that for a 10-min. interval between flushes and for a 1-hr. rush period the pipe will be filled to its capacity for all five water-closets once in 45,600 years. On a similar basis for four water closets the soil pipe will be filled to capacity once in 456 years.

The answers to the problem indicate the absurdity of providing for the simultaneous discharge from all water closets installed. The Hoover Report states,* in this connection:

The question of what frequency of occurrence should be provided for an installation is one closely connected with the establishing of a reasonable factor of safety, and the dividing line should vary with the size and character of the installation.

It should be kept in mind that this is a factor of safety in functioning and that it materially differs from a structural factor of safety. A strain on the system sufficient to use up the entire factor of safety can result in no more than a temporary decrease of functioning and no

* Pages 98 and 146.

TABLE 92.—PROBABILITY OF SIMULTANEOUS USE OF FIXTURES
(Selected from Tables 2 and 3 of final report of the Hoover Committee, pp. 97 and 98)

Actual number of water closets installed	Rush period, hours per day	Number of water closets to be considered as overlapping discharge for 4 sec. or more, 10 sec. per flush		Frequency of occurrence. Once in	
		10 min. between flushes	5 min. between flushes	10 min. between flushes d = days y = yr.	5 min. between flushes d = days y = yr.
3	1	2	...	5.6*d*	
3	2	2	2	2.8*d*	1.4*d*
3	3	2	2	1.8*d*	1.0*d*
3	10	...	2	...	0.3*d*
3	1	3	...	4.5*y*	
3	2	3	3	2*y*	208*d*
3	3	3	3	1.5*y*	139*d*
3	10	...	3	...	40*d*
4	1	3	...	415*d*	
4	2	3	3	208*d*	50*d*
4	3	3	3	139*d*	35*d*
4	10	...	3	...	10*d*
4	1	4	...	456*y*	
4	2	4	4	228*y*	28*y*
4	3	4	4	152*y*	19*y*
4	10	...	4	...	6*y*
5	1	4	...	90*y*	
5	2	4	4	45*y*	6*y*
5	3	4	4	30*y*	4*y*
5	10	...	4	...	1*y*
5	1	5	...	45,600*y*	
5	2	5	5	22,800*y*	1,427*y*
5	3	5	5	15,200*y*	950*y*
5	10	...	5	...	285*y*
6	1	4	...	30*y*	
6	2	4	4	15*y*	1.9*y*
6	3	4	4	10*y*	440*d*
6	10	...	4	...	146*d*
6	1	5	...	7,600*y*	
6	2	5	5	3,800*y*	1,021*y*
6	3	5	5	2,520*y*	680*y*
6	10	...	5	...	204*y*
8	1	4	...	6*y*	
8	2	4	4	3*y*	139*d*
8	3	4	4	2*y*	91*d*
8	10	...	4	...	29*d*
8	1	5	...	816*y*	
8	2	5	5	408*y*	23*y*
8	3	5	5	272*y*	15*y*
8	10	...	5	...	5*y*
10	1	4	...	2.1*y*	
10	2	4	...	402*d*	
10	3	4	...	263*d*	
10	1	5	...	180*y*	
10	2	5	5	90*y*	6*y*
10	3	5	5	60*y*	4*y*
10	10	...	5	...	1*y*
10	2	...	6	...	330*y*
10	3	...	6	...	226*y*
10	10	...	6	...	67*y*
12	1	4	...	335*d*	
12	2	4	...	168*d*	
12	3	4	...	113*d*	
12	10				
12	1	5	...	56*y*	
12	2	5	5	28*y*	1.8*y*
12	3	5	5	19*y*	1.2*y*
12	10	...	5	...	131*d*
12	1				
12	2	...	6	...	77*y*
12	3	...	6	...	51*y*
12	10	...	6	...	15*y*

structural depreciation, except in the matter of overflowing or flooding, which has no direct connection with the matter of venting. It is evident from the maximum carrying capacity of stacks, which is greatly in excess of the rated "practical capacity" used in fixing the limits of service for a stack, that the factor of safety would have to be greatly exceeded before any material reduction of efficiency of functioning occurred. Apparently, then, the only danger is from overflowing or flooding, and this only when the estimated "peak load" for the system approaches the maximum carrying capacity of the stack, which is three or more times the rated practical capacity. The matter of local flooding of lateral branches must be considered separately from the requirements for stack vents and house drains. The greatest danger of overflowing or flooding, except local, is from complete stoppage of the stack or house drain, which may occur for any size of stacks and even with small loads. In view of the preceding relations of frequency of occurrence in the probability tables, it seems reasonable to assume that an estimated peak load occurring once in the order of one year is ample allowance for fixing the size of stacks, vents, and drains to the nearest size, and to assume that a coincident discharge occurring once in the order of 10 or 100 years may be neglected.*

241. The Toilet or Bathroom.—The question of the proper arrangement of the fixtures in a bathroom; the heating, the ventilation, and the illumination of the room; the materials for the floors, walls, ceilings, etc. are of equal importance to the type of fixtures, the capacity of the drain pipes, and other problems in connection with a successful plumbing design. The best fixtures available, connected to adequately designed and properly roughed-in drainage pipes, installed in a poorly ventilated and poorly lighted room can not be expected to give satisfaction and comfort to the user. Only a few principles and conditions of practice in heating, ventilating, and illuminating plumbing and bathroom installations will be given here. For complete discussion of the fundamentals and an explanation of details reference should be made to standard works on heating and ventilation.

242. Illumination.—Illumination from an outside window or skylight is essential to the proper natural lighting of a bathroom. Light should not be cut off from the window or skylight by trees, buildings, walls, or other obstructions. Where it is not possible to obtain such natural illumination artificial illumination must be depended upon. The amount of artificial illumination in a private

* Page 146.

bathroom is usually a matter of taste and exceeds actual needs. A light placed high and near the center of the room is usually sufficient when the walls, ceiling and floor are white or light colored. Additional lights are often placed on wall brackets, usually one or two near the mirror over the lavatory. It is desirable, as a matter of safety, to place all electric switches beyond the reach of a person standing in the bathtub.

243. Heating.—Heating may be by steam, hot water, or warm air. Gas, oil, or other open-flame heaters are undesirable in any room, but particularly in a bathroom, because of its small size and impervious floor and wall construction, unless special provision has been made for ventilation. In the ordinary unventilated bathroom in a private home the presence of an open-flame heater in the room with both door and window shut may result in death to the user. For the same reasons that ventilation is desirable the required amount of heat is small.

In order to keep the required amount of heat small the bathroom should be located in a protected part of the building with only one outside wall; the wall space being used for window, radiator, or built-in closet space. The use of an open fireplace in a bathroom gives an unusual feature of delightfulness to the room and provides a generous and adequate ventilation. The use of an open-flame heater, such as gas logs, in an open fireplace is justifiable and permissible.

244. Ventilation.—The ventilation of a bathroom in a private dwelling house usually depends on the door and the window or skylight. In some private homes the bathroom door and window may be so substantially built and closely fitted as to afford no ventilation and violent opening or closing of the door may destroy or seriously weaken the seal of traps on fixtures in the room. Since the cleanliness of a bathroom and the absence from undesirable odors are dependent, to a great extent, on illumination and ventilation, some form of ventilation other than the door and the window is desirable in private homes and is essential in public toilet rooms. It is sometimes required in plumbing codes that the toilet room be so ventilated that the air will be changed at least six times per hour.

The change of air in a toilet room may be caused by forced or natural draft. Forced draft is caused by fans, blowers, or special heating apparatus. Natural drafts, which are commonly used in small buildings, are caused by the use of flues and large air-duct

openings. Local vents on closets and urinals give the best form of ventilation when these are attached to vents with forced draft. Local vents depending on natural draft are of little value. Each closet vent should have an area of 8 to 10 sq. in., and each urinal double this amount. The individual vents should join in a single main vent which should extend through the roof. It is permissible to lead local vents into a smoke flue but in this case the area of the vent should not exceed one-tenth of the area of the flue. Vents through registers placed in the wall immediately behind the closet seat are sometimes looked upon with more favor as being less noticeable to the user and equally successful in removing odors from the room.

245. Housing Codes.—Few plumbing codes adequately cover the requirements for ventilation which are more commonly classed under housing conditions. In some governmental jurisdictions, either state or municipal, where the plumbing code is silent on such points, the building code, the housing code, or some other law, regulation, or ordinance will cover the point. The requirements of the Wisconsin State Plumbing Code, issued by the State Board of Health in 1925, in regard to ventilation will indicate general rules for good practice:

Sec. 5253. **Location, Light, Ventilation.**—Every toilet or bathroom shall be so located as to open to the outside light and air by windows or skylights opening directly upon a street, alley, court, or vent shaft, except as hereinafter provided. Every such vent shaft shall have a horizontal area of at least 1 sq. ft. for each water closet or urinal adjacent thereto, but the least dimension of such shaft, if one story high, shall not be less than 3 ft.; if two stories high not less than 4 ft.; and one additional foot for each additional story.

The glass area for a toilet room containing 1 closet or urinal shall be at least 4 sq. ft., with 2 sq. ft. additional for each additional closet or urinal.

In addition to the windows herein required, each toilet room which contains more than 3 fixtures (closets and urinals) shall have a vent flue of incombustible material, vertical or nearly so, running through the roof, with cap or hood of the siphon type, or its equivalent, and the vent shall be not less than the following sizes:

Four fixtures	8-in. pipe
Five or six fixtures	10-in. pipe
Seven to ten fixtures	12-in. pipe

But if the windows or skylights can not be opened, then vent pipes shall be provided as specified in Sec. 5254.

No toilet room shall have a movable window or ventilator opening on any elevator shaft or any court which contains windows of sleeping or living

rooms above, except that a toilet room containing not more than two closets may have a movable window on such court, provided such room has a vent flue running above the roof.

Sec. 5254. **Location without Outside Windows—When Permitted.**—If a location with outside windows is impracticable, a different location will be permitted as follows:

1. For a toilet used by not more than three persons, without special permit.

2. For a toilet in a new building, used by more than three persons, only with the written approval of the Industrial Commission or the State Board of Health, or their authorized agents.

3. For a new toilet in an existing building, used by more than three persons, only with the written approval of the Industrial Commission or the State Board of Health or their authorized agents.

Such approval shall be granted only where a location with outside windows is not reasonably possible.

Where a toilet room without outside windows is permitted it shall have a fixed window or windows to an adjoining room, with glass area as provided above, arranged so as to furnish as much light as possible. Frosted or other translucent glass shall be used when necessary for privacy. In no case shall the floor be of wood. A vent flue of incombustible material shall be provided, vertical or nearly so, running through the roof, with a cap or hood of the siphon type or its equivalent, and the vent shall be not less than the following sizes:

One fixture (closet or urinal)	6-in. pipe
Two fixtures	8-in. pipe
Three fixtures	10-in. pipe
Four or five fixtures	12-in. pipe
Six or seven fixtures	14-in. pipe
Eight to ten fixtures	16-in. pipe

Notes.—(1) Glass area 50 per cent greater than required is recommended.

(2) An air inlet is recommended if it can be made sound proof.

(3) A fan in the flue will be required if necessary for proper ventilation. If there is no fan a steam coil, or even an electric light at the bottom of the flue (*or any method for heating the flue*)* will help to produce circulation. Where a metal vent pipe extends above the roof, a double pipe or other insulation against cold, is recommended.

(4) Closets provided with a local vent are recommended and may be required in some cases before approval is granted.

Sec. 5255. **Artificial Light.**—Every toilet room, except in a private apartment, shall be artificially lighted during the entire period that the building is occupied, wherever and whenever adequate natural light is not available, so that all parts of the room are easily visible.

Sec. 5256. **Size.**—Every toilet room shall have at least 10 sq. ft. of floor area, and at least 100 cu. ft. of air space, for each water closet and each urinal.

* Inserted by author.

Sec. 5257. **Floor.**—The floor and base of every toilet room shall be constructed of material (other than wood) which does not readily absorb moisture and which can be easily cleaned; except that wood floors may be used in

1. Private apartments.
2. If approved in writing by the Industrial Commission or the State Board of Health or their authorized agents, in existing buildings where there is an existing wood floor in good condition and where such toilet will be used by not more than five persons; provided further that such room must have an outside window or skylight.

Sec. 5258. **Walls and Ceilings.**—The walls and ceilings of every toilet room shall be completely covered with smooth cement or gypsum plaster, glazed brick or tile, galvanized or enameled metal, or other smooth, non-absorbent material. Wood may be used if well covered with two coats of body paint and one coat of enamel paint or spar varnish. But wood or like material shall not be used for partitions between toilet rooms, nor for partitions which separate a toilet room from any room used by the opposite sex. All such partitions shall be as nearly sound-proof as possible.

In large rooms a hose connection and floor drain should be provided.

Sec. 5259. **Partitions between Fixtures.**—Adjoining water closets shall be separated by partitions. Each individual urinal or urinal trough shall be provided with a partition at each end and at the back, to give privacy.

Where individual urinals are arranged in batteries, a partition shall be placed at each end and at the back of the battery. A space of 6 to 12 in. shall be left between the floor and the bottom of each partition. The top of the partition shall be between 5½ to 6 ft. above the floor. Doors with the top 5½ ft. above the floor and the bottom 6 to 12 in. above the floor shall be provided for all water-closet compartments.

Water-closet compartments shall be not less than 30 in. in width, and shall be sufficiently deep to permit the door to swing past the fixture when opened.

Recommendations.—It is recommended that doors be equipped with a spring or other device so that they will remain open when the compartment is vacant, and will need to be latched to hold shut when the compartment is occupied.

Note.—Wood is not recommended for compartment enclosures; if used it should be hardwood. Toilet compartments should in no case be less than 30 by 52 in. in clear.

Recommendation on Service Closet.—When practicable a service closet conforming with requirements for construction of toilet rooms shall be provided and supplied with cleaning tools, soap, toilet paper, and toweling necessary for sanitary upkeep of toilet rooms.

246. Toilet and Bathroom Interiors.—Toilet and bathroom floors and walls for a height of at least 3 or 4 ft., in private dwellings as well as in public buildings, should be of an impervious material which is easily washed. Among the satisfactory materials frequently used are included vitrified white tile for the floor and enameled brick for the wall. Although white is

very desirable for the walls, floor, and ceiling, the dead monotony of it can be broken up by designs, in black or colors, which do not cover sufficient surface area to detract materially from the lighting of the room. An interior view of a modern bathroom in which such materials are used is shown in Fig. 130. Other satisfactory materials sometimes used for floors include terrazzo, asphalt, concrete, or hardwood well laid and impregnated with a waterproof coat of linseed oil. Painted plastered walls above a 10-in. floor or baseboard have proven satisfactory for private residences, but they do not present an appearance of elegance nor

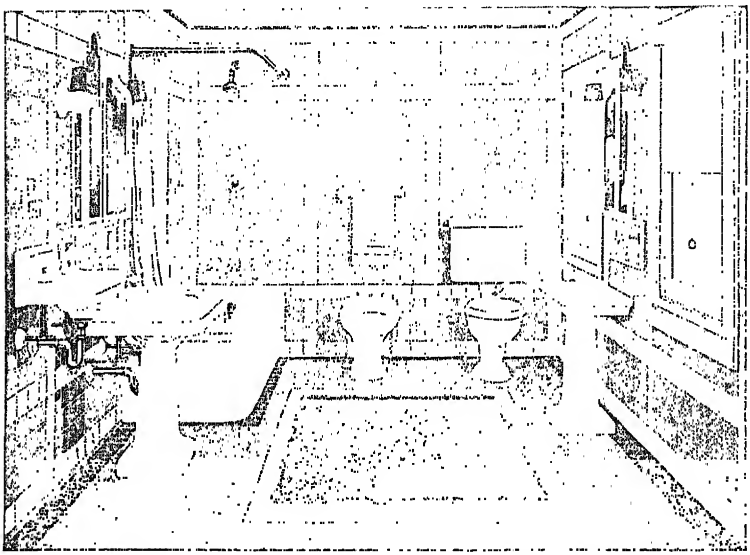


FIG. 130.—An interior view of a completely equipped bathroom. (*Courtesy of The Trenton Potteries Co.*)

of present-day style nor do they afford the ease in cleaning resulting from the use of white or enameled tile or other impervious and smooth wall materials. In public toilet rooms slate may be used to form the walls of the toilet compartments. The dimensions of standard toilet inclosures are shown in Table 144.

247. Bathroom Fixtures.—The fixtures most commonly included in the bathroom in an American dwelling house of moderated cost include a bathtub, a lavatory, and a water closet. The bathtub may have a shower bath attachment. As the cost of the bathroom equipment increases the elegance and number of

fixtures will increase. Additional fixtures may include a sitz bath or bidet, a foot tub, a baby bath, a shower bath cabinet, etc. It is sometimes desirable to place the water closet in a different room than the bathroom. This arrangement permits the use of the water closet when the bathroom is occupied. Where a large family is dependent on one water closet the room will frequently be occupied when one or more other persons wish to make use of it. The water closet in a separate compartment will aid in reducing the number of times in which this situation may arise.

Bathroom accessories include soap cup, tumbler and tooth brush holder, coat hook, towel rack, shelf, toilet paper holder, soap cup for bathtub, medicine chest, and other incidentals. Some, but not all, of these accessories may be provided by the designer of the building and installed by the plumber.

The arrangement of the fixtures within the bathroom is a matter of personal taste to be determined by the owner or the architect based upon the needs for heating, ventilation, illumination, and convenience. No fixture should be placed against an outside wall and economy in roughing-in will demand attention in the design. The greatest economy can be approached with the least amount of piping and fittings. The bathroom equipment and the roughing-in shown in Fig. 111 represent an inexpensive and satisfactory arrangement. It is generally possible, but sometimes expensive, for an ingenious plumber to provide for any desired arrangement or location of the fixtures, but in order to avoid expense care should be observed that venting, drainage, and water supply can all be obtained by the use of a few standard fittings and but little pipe.

248. Water Closets.—The desirable features in a water closet include comfort to the user, cleanliness, adequate flushing, silence in operation, small water consumption, air tightness and water tightness where required, and suppression of odors.

249. Water-closet Seats.—Comfort to the user is secured through the style of the seat, its height above the floor, and the material of which the seat is made. It is not possible to suit all persons in these regards but, in general, a height of about 15 in. above the floor is satisfactory. Some persons prefer a seat sloping downwards towards the rear. The seat should be made of some material which will not absorb moisture, is a poor conductor of heat, is easily cleaned, and is one solid piece without joints or cracks visible on the surface. Seats made of varnished

hardwood riveted, bolted, or glued together are probably the most common types in use but they can seldom fulfil the requirements enumerated above and they are being rapidly displaced by more comfortable and durable types.

The seat should be securely fastened to the bowl, it should rest solidly on the rim, and a cover should be provided. The shapes and dimensions of various seats are shown in Figs. 131 and 132. The selection of any particular type of seat for a private home is dependent on the choice of the householder. Medical statistics show the importance of selecting the open-

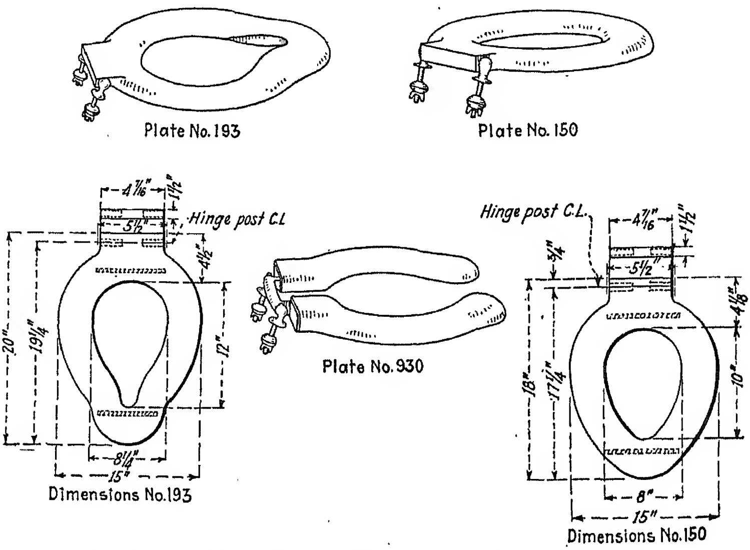


FIG. 131.—Types of toilet seats. *(Courtesy Church Seats.)*

front type of seat. The projecting lip bowl is also essential to cleanliness in public toilets. The depth and shape of the bowl and the location of the standing water should be such that the user is not splashed and urine is not spilled over the edge of the bowl.

The seat should be located so that there is room for the user between walls and fixtures. If placed in a corner the center of the seat should be 12 to 14 in. or more away from any wall, or if placed near another fixture a plumb line through the nearest part of the adjacent fixture should be 12 to 14 in. or more away from the center of the seat. In public comfort stations the

privacy of the user should be secured by placing the water-closet fixture in a separate compartment. The use of range closets is undesirable from the viewpoints of comfort and sanitation.

250. Suppression of Odors.—Odors can be minimized by means of a local vent. Air movements are maintained through this vent by either natural or forced draft. The operation of the water closet should be simple, self-cleansing being obtained by self-siphonage, and flushing by the pushing of a button or handle or by the pull of a chain. Complicated closets with tipping pans, ornate scroll work, etc. are to be avoided.

251. Cleanliness.—Cleanliness is obtained by the use of white vitreous ware or enameled iron and the construction of a bowl in which all wet parts above the trap are visible and accessible with smooth easy curves and without reentrant angles or niches in which filth may accumulate. Vitreous ware or all porcelain is almost exclusively used today for water-closet bowls in well appointed toilets and it is highly recommended because it can be made to fulfill all of the requirements of an ideal water-closet bowl. Enameled iron does not present so attractive an appearance and stains more easily but its use is recommended where hard usage is to be expected as in some public comfort stations, factories, jails, etc. The shape of the bowl should be such that fecal matter does not become stranded on the dry portion of the bowl but either floats on the water in the bowl or falls to the bottom of the trap. This condition is secured by the use of a short front length of the bowl with a steep slope of the unsubmerged portion and placing the pool of water beneath the middle and rear portions of the opening in the seat.

The splashing of urine from the bowl and the soiling of the front edge of the seat are avoided by dividing the seat, as shown in Fig. 131, and increasing the height of the bowl a slight amount. The water closet should be set away from other fixtures and no protective box, wall, or other construction should be placed around it to decrease accessibility to front, rear, and sides, either inside or outside. A difficulty encountered with the present-day type of water closet, and for which no adequate remedy has been devised, is the dropping of urine on the floor around the seat. Only open plumbing and constant vigilance in maintenance can prevent undesirable results from this condition.

252. Types of Water Closets.—Many types and styles of water closets are available on the market, some of which are shown

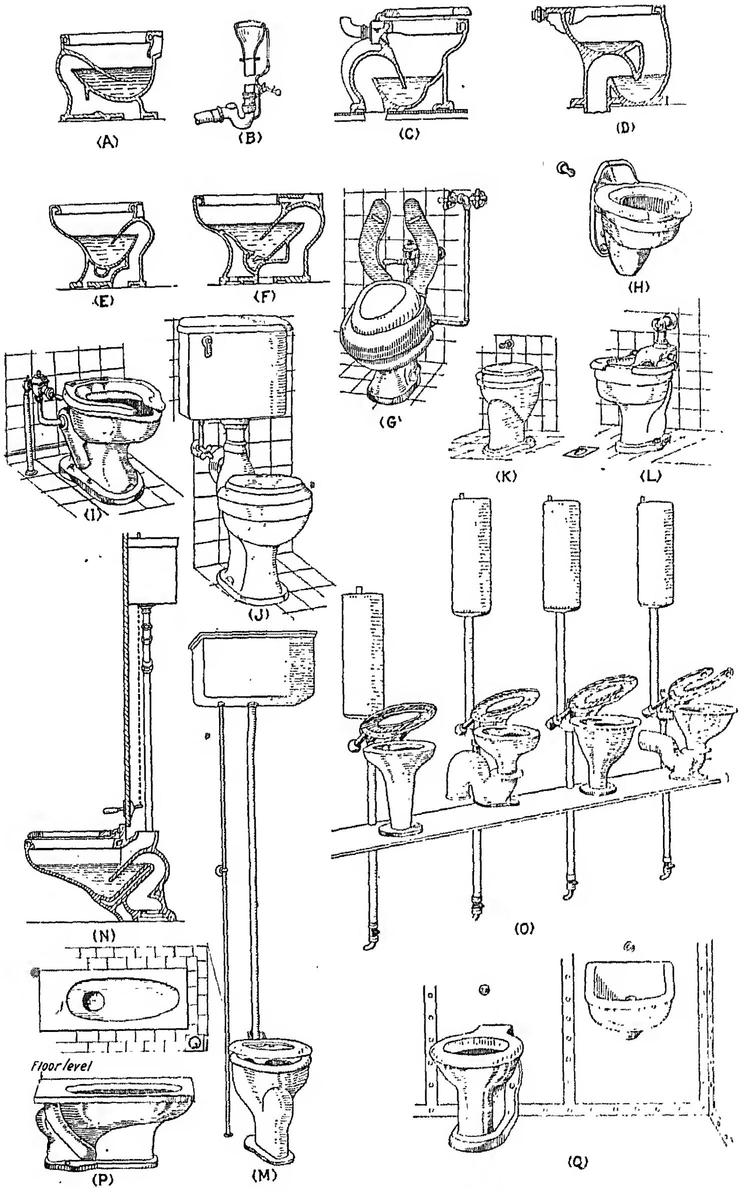


FIG. 132.—Types of water closets.

in Fig. 132. Practically all can be grouped under the following classifications: wash-down closet, wash-out closet, hopper closet, and siphon closet. The siphon closets are divided into three types: the siphon action, the reverse trap, and the siphon jet. The first named is the least expensive. The reverse trap has the advantage over the siphon action in that it contains less water and a deeper seal, hence giving a quicker and more positive action. The siphon-jet closet has all of the advantages of the reverse trap and in addition has a stronger action in cleansing itself.

The wash-down and the wash-out closets depend on the force of the flushing water to remove deposits. As this is less effective and the closet is more subject to fouling and splattering than siphon-action closets their use is not recommended, although the wash-down closet is better than the wash-out type.

A dry-hopper closet contains water only in the trap. A pedestal-hopper closet contains water in the bowl as well as in the trap. Short-hopper and pedestal-hopper closets have the trap above the floor. The former are more desirable in order that the water in the trap may be observed and the area of surface exposed to fouling above the trap is less. The long-hopper closet finds its use mainly in unheated compartments. In general, hopper closets are undesirable because of the area of dry surface exposed to fouling above the water in the trap.

Siphon or siphon-jet closets, with the trap above the floor in plain sight, are the most satisfactory types of water closets now in use.

Explanation of Fig. 132.

(A) Siphon-action closet. (*Trenton Potteries Company.*)
(B) Frost-proof hopper closet
(C) Wash-down closet.
(D) Wash-out closet.
(E) Reverse-trap, siphon-action closet. (*Trenton Potteries Company.*)
(F) Siphon-jet closet. (*Trenton Potteries Company.*)
Note the flushing rim on each of the above sections.
(G) Split seat, with flush valve, and bed-pan rinsing attachment. For use in hospitals. (*Trenton Potteries Company.*)
(H) Wall-hung closet leaving floor clear beneath the closet. Straight roll rim with open seat. Concealed flush valve with handle in wall. (*Sanitary Earthenware Supply Company.*)
(I) Extended lip bowl; open seat; exposed flush valve. (*Imperial Brass Manufacturing Company.*)
(J) Low-down tank; ordinary seat with cover. (*Thos. Maddock.*)
(K) Fixture clear of wall, no exposed piping. Concealed flush valve with handle in the wall. (*J. L. Mott Company.*)
(L) Raised rim; open seat; foot action flush valve. (*J. L. Mott Company.*)
(M) High-up tank; seat-action valve. (*Kohler.*)
(N) Concealed high-up tank with handle for flushing in the wall. (*Trenton Potteries Company.*)
(O) Hopper closets with pneumatic flush tanks. (*I. X. L. Company.*)
(P) Pit or squat closet with foot-action flush valve. The top of the closet is flush with the floor. (*J. L. Mott Company.*)
(Q) Integral rim; wall push button; lavatory. Prison plumbing. (*J. L. Mott Company.*)

253. Frostproof Water Closets.—Frostproof water closets should not be installed in compartments which have a direct connection with any dwelling or building used for human occupancy. The compartments enclosing such closets should be well constructed, lighted, and ventilated, as they are subject to neglect under the best of circumstances. The soil pipe between the hopper and the trap should be 3 in. in diameter and should be made of lead or cast iron. The hopper pipe should not be more than 6 ft. in length.

The closet should be so arranged as to be adequately flushed and the water-supply pipes and the trap should be adequately protected from freezing by placing them below the frost line. Access to the trap should be provided by a manhole.

Where the closet is located at the upper end of a soil line the soil line should be vented with a pipe not less than 2 in. in diameter carried above the roof of the closet and terminating 12 ft. or more away from or 3 ft. or more above any opening into a building.

254. Flushing of Water Closets.—Water closets are flushed by high-up or low-down tanks, direct flushing valves, or by pneumatic tanks. The various flushing devices are shown in Fig. 132. High-up or low-down tanks should have a capacity of 5 to 8 gal., a flush valve should be able to deliver water at the rate of 45 to 50 gal. per minute under normal minimum pressure, and a pneumatic tank should have a total capacity of about 6 gal.

255. Flushing Tanks.—Because of the need for supplying water at a rate of 30 to 50 gal. per minute the supply pipe from the flush tank to the closet bowl should be of generous size, the lower down the tank the larger the size of the pipe. A high-up tank, placed 7 to 8 ft. above the floor, should have at least a 1¼-in. pipe to the closet bowl. These flush pipes are usually made of thin brass tubing, either plain or nickel plated, and are joined to the closet bowl by slip joints so as to furnish some flexibility to allow for movements of the closet bowl. Since it is not necessary to supply the water under pressure low-down tanks with large flush pipes are successful in operation. The flush valve on any fixture should be placed above the fixture and should be so connected that there is no possibility of back flow from the fixture into the water-supply pipes.

The working parts of a low-down flush tank are shown in Fig. 133. The details of the float-controlled valve are shown in Fig.

59. The mechanism of this tank is similar to all gravity flush tanks, to which class both high-up and low-down tanks belong. The mechanism operates as follows:

When lever *F* is raised the rubber ball *H* is lifted off of its seat and it is held at *G* by flotation. Water rushes out of the tank and ball *I* drops, opening the supply valve *B*. When the water level reaches *G* ball *H* begins to drop and is suddenly pulled on to its seat by suction thus cutting off the flush. Valve *B* is supplying water to refill the tank through tube *D*. This tube is bent down to discharge water into the tank below the water level in the tank in order to maintain a silent flow. Water is also supplied from valve *B*, through pipe *A*, to the closet bowl in order to renew the seal in the trap. When float *I* reaches its original position, valve *B* closes and the tank is ready for the next flush.

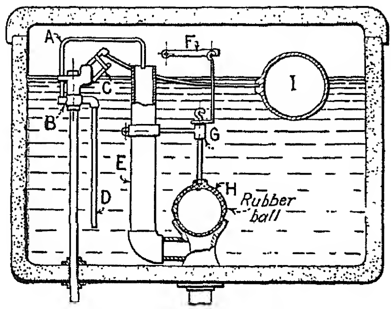


FIG. 133.—Working parts of a water-closet flush tank.

All float-controlled or automatically controlled valves which discharge into fixtures, traps, or elsewhere should, where possible, be so installed that leakage from the valve is visible.

Because of the noise in connection with the operation of high-up tanks, their unsightliness, and the success in overcoming these objections by the use of low-down tanks the latter are being installed almost entirely in new installations. Noises are not always suppressed by the use of the low-down tanks but they are not subjected to the noise of water falling from a height which is an unsuppressible accompaniment to the use of the high-up tank.

256. Flushing Valves.—Flushing valves take water directly from the water-supply pipes at city pressure and deliver it directly into the closet bowl, thus doing away with noisy tanks and standing water and giving a short flush at a high rate. The amount of water delivered at one flush can be adjusted automatically and with a properly designed bowl, flush valves will operate with less water than would be required by a flush tank. The operation of a flush valve is illustrated in Fig. 69.

Flush valves or similar devices should be provided with individual controlling stops and should be connected to a water supply which will maintain a pressure of not less than 5 lb. per square inch when it is flushing. The valves should be constructed so that they cannot be held open for continuous discharge, and they should fulfil the conditions stated below without requiring regulation if the static pressure varies from 5 to 75 lb. per square inch. The quantity of water discharged by each device should be within the following limits:

Water closets and slop sinks, each...........	3	to 5	gal.
Pedestal or siphon-jet urinals, each..........	2	to 2½	gal.
For each 20 in. of urinal trough.............	2	to 2½	gal.
Flush rim or individual stall urinal..........	¾	to 2	gal.

In the installation of flush valves care should be taken that water cannot back out of the fixture into the water-supply pipes when the pressure in the water-supply pipes is low or the water-supply pipes are drained. This can best be done by installing the fixture so that the end of the pipe cannot be submerged. If the fixture is designed so that the end of the supply pipe is submerged a check valve may be installed. This protection is inadequate, however, in view of the danger to health and life which might result from the siphoning of the contents of a water-closet bowl into the water-supply pipes.

An insurmountable obstacle to the use of flushing devices, which excludes them from the majority of ordinary dwellings, is the large size of supply pipe needed. As shown in Table 34, this size should not be less than 1¼ in., and it should preferably be larger. Flush tanks to be used in connection with flush valves are manufactured but their use is not common.

256*a*. Pneumatic-flush Tanks.—A pneumatic-flush tank is shown at O in Fig. 132 and the details of the pneumatic-flush valve are shown in Fig. 134. The valve operates as follows:

When the seat, attached to the arm *A*, is pressed down, valve *B* is pressed on its seat and shaft *C* is raised through arm *D* acting at fulcrum *E*. This raises sleeve valve *F* so as to uncover the inlet port *G* and cover the waste port *H*. Water from the supply line enters the pneumatic tank *J* compressing the air therein. When the seat is raised sleeve valve *F* drops back to cover the inlet port *G* and at the same time flush valve *B* is raised from its seat and waste port *H* is uncovered. A strong flush of water passes into the toilet seat and all excess water is drained from the tank and valve through the waste valve *H*.

257. Rate, Time, and Quantity of Flush.—The rate of supply of water from any flush tank or valve to the toilet bowl must be adjusted to the shape of the toilet bowl and its passages.

If the rate of supply is too low* a complete break in the siphon action occurs and in extreme cases the minimum point approaches zero while the bowl is refilling following the first siphon action. This action is shown graphically in Fig. 135A. The result is a sluggish and uncertain

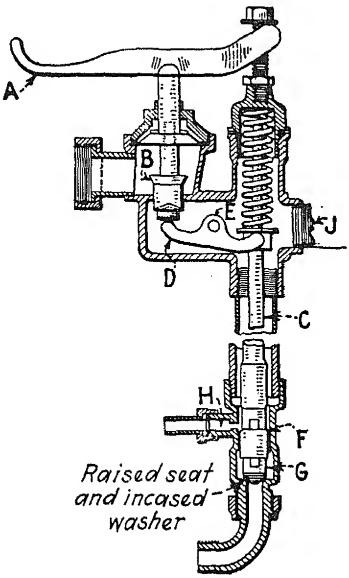


FIG. 134.—Seat-action valve for use with pneumatic tank on frost-proof water closet. (*I. X. L. Company.*)

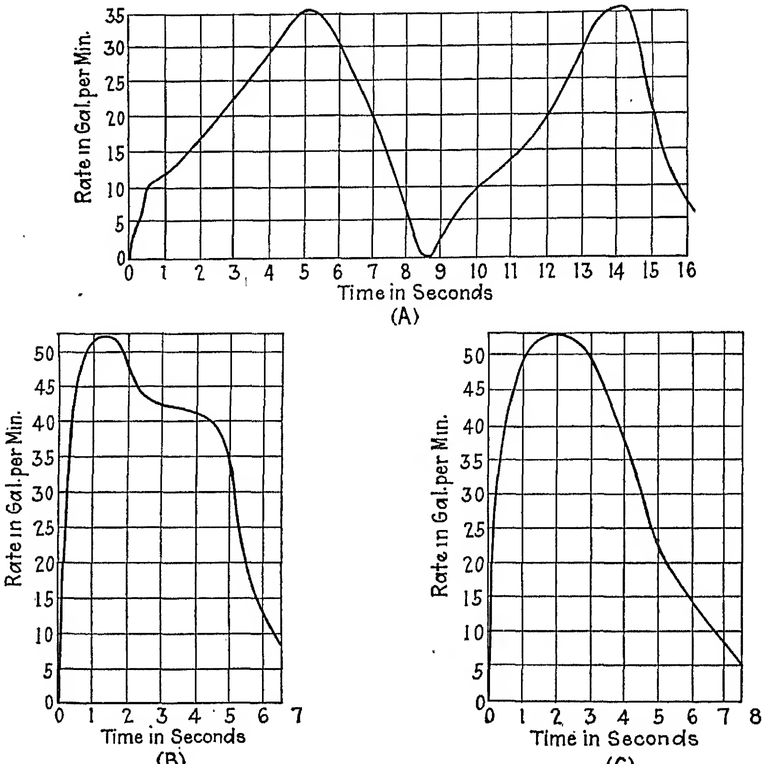
flush. If the rate of supply is too high the siphon action becomes continuous with the bowl partly filled until the end of the flush.

This condition is illustrated in Fig. 135C. Other conditions of flushing are shown in Fig. 135B. The results of tests on rates of flushing water closets, made at the United States Bureau of Standards are recorded in the Hoover Report. It is stated therein that:

It is impossible to fix a definite value for either the rate of supply or the total quantity of water which will give the best results for all water closets . . . There are however, pretty definite limits within which the

* From Hoover Report, p. 80.

serviceable rates for all water closets employed in these tests and we believe for all water closets that should be approved for general use, fall . . . A mean value of approximately 30 gal. per minute is a rate of supply that, in general, will prove satisfactory . . . The quantity of water required depends on the duration of the flush. The time varies from 6 to 10 sec. . . . This . . . indicates a range of from 3 to 5 gal. as a serviceable quantity. No doubt there are many closets on



(A) Sluggish and uncertain flush. (B) Good condition. (C) Rate of supply too high.
FIG. 135.—Rates of discharge from water closets. (*Hoover Report.*)

the market which a smaller quantity would serve satisfactorily under certain conditions. The approximate mean values are, therefore, 4 gal. supplied at the average rate of 30 gal. per minute for 8 sec.*

The flushing water, from whatever source, should be injected into the closet bowl from a flushing rim and through larger

* From Hoover Report pp. 81, 82.

openings through the back of the seat, as shown in Figs. 132A to F, inc. The flush should be so distributed as to wash down the walls of the bowl. It should come with sufficient rapidity to cause the trap to siphon itself once only. The self-siphoning of the trap is essential to the carrying away of solid matter. A continuously running, non-siphoning bowl will not cleanse itself. The siphonage is sometimes accelerated and the cleansing increased by the use of a jet at the bottom of the trap, as shown in Figs. 132E, F, and N.

In studying the graphical presentation of rates of water-closet flushing from Hoover it will be noted in Fig. 135A that the curve reaches two maxima, the first at about 45 gal. per minute and the second at 26½ gal. per minute. This is due to a double self-siphonage action which does not show in Fig. 135B. The curve in Fig. 135C illustrates a desirable rate-time discharge curve with proper siphoning action in the water-closet discharge.

258. Noises in Operation.—The noise in the operation of a water closet may be due to any one or a combination of causes including the operation of the water-supply valve, the sucking sound due to siphonage, and the splashing of water. All can be suppressed so as to give almost silent operation, but loss of adjustment may restore any one of the causes. Other factors entering into the production of the noise are small, high-velocity streams, the rattling or singing of washers, and similar mechanical difficulties. Among the prolific causes of noise, and the producer of the most penetrating sounds heard throughout a building, are the results from the slow closing of the water-supply valve which releases a small stream at a high velocity resulting in a high, piercing whistle. The closing of a flush valve may result in a similar noise. Adjustment of the valve may overcome this noise.

The noise made by the sucking of the siphon and the splashing of water cannot be stopped completely, but not being of a penetrating nature the noise can be suppressed by lowering the seat cover during the flush.

259. Construction of Water Closets.—Water tightness and air tightness are obtained by casting the entire fixture in one piece with a generously sealed trap and a proper floor connection. The passages should be sufficiently large to pass a 2⅞-in. ball; the depth of the seal of the trap should not be less than 3 nor

more than 4 in.; and the amount of water in the trap is in the neighborhood of 3 quarts.

260. Installation of Water Closets.—The connection between the bowl and the drainage pipes must be made with special care and attention because of the vibration and movement to which it may be subjected. The weight of the bowl should be supported on the floor and should not rest on the pipe. The bowl and the pipe are, therefore, seldom subjected to the same shocks and seldom move together. The flexibility of the joint

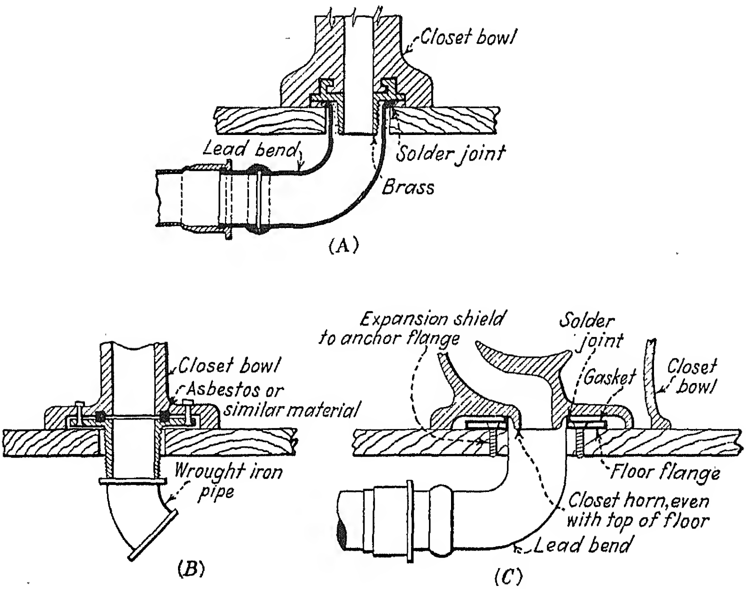


Fig. 136.—Types of water-closet floor connections.

must be depended on to take up this movement and to preserve a tight seal to the joint. Types of floor connections are illustrated in Fig. 136. The flexibility of Figs. 138A and 136C is secured through the lead bend, and in Fig. 136B through the asbestos gasket. The joints are illustrative of a few of the many types of closet floor connections each of which includes an allowance for movements between the water-closet bowl and the soil pipe. Putty, plaster of Paris, or slip joints, should not be used on closet connections.

The connection between soil pipe and fixtures of earthenware, vitreous china, or enameled iron should be made with a solid

brass floor plate or cast-iron floor plate, not less than $\frac{3}{16}$ in. thick, soldered, screwed, or calked to the bend or the pipe, securely anchored to the floor and bolted to the trap flange. The joints should be made air tight with an adequate asbestos graphite ring, asbestos gasket washer, rubber gasket, or perfect screwed joint. A paste of red or white lead or other compound should be used to insure the tightness of the joint. In wooden joint construction the connection between earthenware and soil pipe should have a length of not less than 2 in. of lead pipe between the wiped joint and the underside of the floor, as shown, for example, in Fig. 136A.

A brass floor connection should be wiped or soldered to lead pipe; iron floor connections should be calked to cast-iron pipe; or an iron floor connection should be calked or screwed to wrought pipe and the floor connection bolted to an earthenware trap flange. A metal to earthenware or a metal to metal union, or a lead or asbestos washer should be used to make a tight joint.

References

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2. Moffett, T. F., "Representative Bathroom Layouts," *Plumbers Trade Jour.*, p. 502, Sept. 15, 1925.
3. *Plumbers Trade Jour.*, p. 415, Feb. 28, 1921.
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CHAPTER XVI

PLUMBING FIXTURES FOR BATHING AND WASHING

261. Bathtubs.—In a well ordered private home the bathtub, or the shower bath, is used more frequently than any other plumbing fixture except the water closet. The shapes, styles, and sizes of bathtubs which are available on the market may be confusing to the inexperienced purchaser whose judgment may be guided by a consideration of similar principles outlined for the consideration of the water closet in the preceding chapter. Among the requisite conditions for a satisfactory bathtub are that it shall be sanitary, comfortable, of pleasing appearance, watertight, easy to install, easy to maintain, and inexpensive.

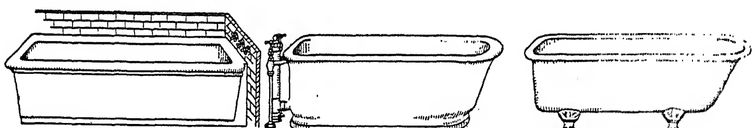


Fig. 137.—Types of bathtubs.

Cleanliness or sanitation is secured by the use of such a shape as to be self-draining and not to offer sharp angles or recesses in which dirt may collect and from which it can be removed only with difficulty. Frequent cleaning, particularly after use, is necessary to preserve a clean surface. Materials which are satisfactory in this respect and which are easily cleaned include enameled iron, earthenware, and marble. Wooden tubs, metal-lined wooden tubs, or unlined or painted iron, copper, or zinc tubs are difficult to keep clean and should not be used. Their use is prohibited by some plumbing codes.

The tub is best made white or light colored without decorative protuberences or recesses either inside or outside. The tub should be supported on legs above the floor and away from the wall so that dirt can be cleaned from beneath or behind it, or it should be built into the wall or floor, or both, so that dirt cannot accumulate either beneath or behind it. The three common

types of bathtubs are known as the built-in tub, the bath-on-base, and the bath-on-legs. These are illustrated in Fig. 137. Tubs are also known by their shape as ordinary, French, and Roman, as shown in Fig. 138.

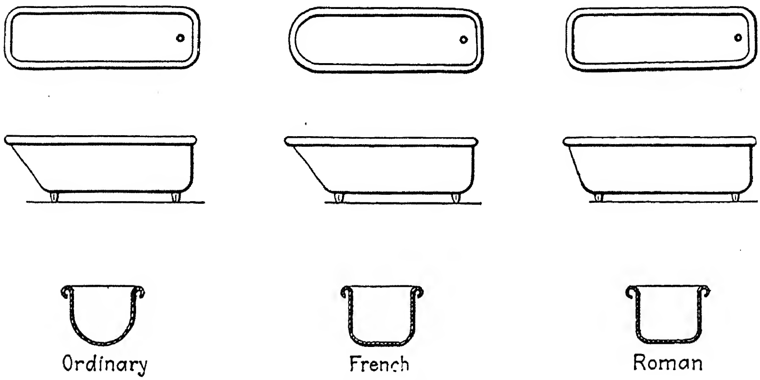


FIG. 138.—Styles of bathtubs.

The built-in bath will occupy less room as it can be placed against the wall, in a corner, or in a recess, as shown in Fig. 139. The connection between the tub and wall, or the tub and the

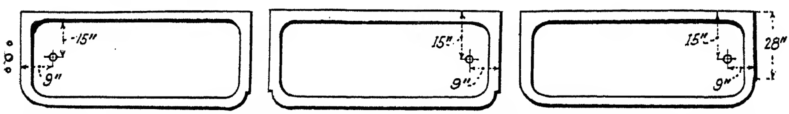


FIG. 139.—Diagram of locations of built-in bathtubs with approximate dimensions.

floor, should be made watertight somewhat as shown in Fig. 140. Where the tub is not built in, or where it is on legs, sufficient space must be allowed for cleaning around and under the tub.

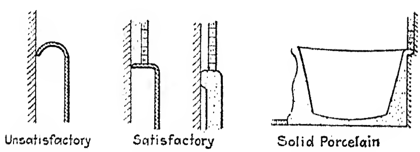


FIG. 140.—Details of connection between wall and built-in bathtub.

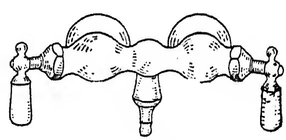
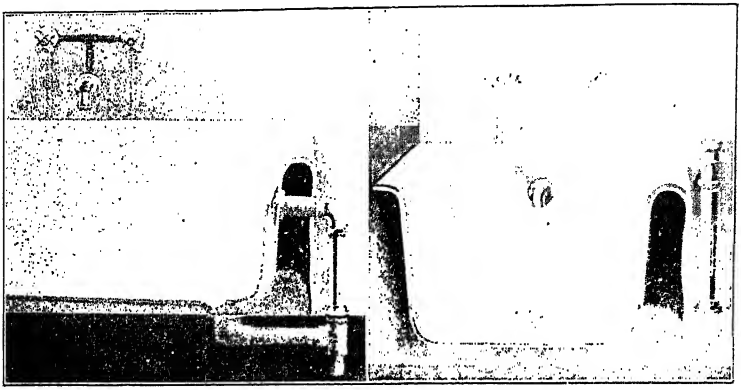


FIG. 141.—Combination faucet placed inside of bathtub.

262. Water Supply to Bathtubs.—Water is admitted to the bath tub in various ways among which a common method is the use of a combination faucet with one outlet and separate hot- and cold-water inlets, as shown in Fig. 141. The advantage

secured from the use of combination faucets lies primarily in the control of the temperature of the incoming water. The faucet handles may be placed directly in the tub, as shown in Fig. 141, or on the wall outside of the tub, as shown in Fig. 142. The placing of the valve handles outside the tub leaves the space within the tub unobstructed. In some installations the water enters the tub through a hole in the side or end. The hole is partially covered by a protruding hood-shaped lip which directs the stream downwards. The lip is sometimes placed very low in the tub so that it is submerged soon after the tub begins to fill. This has the advantage of silence in operation but the control of



Nozzle outside of tub. Plug-and-chain waste. Nozzle inside of tub. Standing waste.

FIG. 142.—Bathtubs with supply-valve handles outside of the tub. (*Courtesy J. L. Mott Company.*)

the temperature of the incoming water is difficult. Sizes of faucets, losses of pressure, and other details in connection therewith are considered in Chap. V. It should be remembered, however, that in all fixtures having both a hot- and a cold-water supply the general custom is to place the hot water faucet on the left.

263. Bathtub Wastes and Overflows.—Water can be drained from a bathtub at any convenient point but the best point is usually nearest to the inlet. The bottom of the tub should slope towards the outlet. The advantage of having the outlet near to the inlet is in the quick discharge of dripping from a possibly leaky faucet without having the water run through the fixture. Comfort to the user is obtained by placing the outlet near one end rather than at the center of the tub.

The size of the outlet is made too small in most fixtures. It is frequently made smaller than the diameter of the branch waste from the tub, and the passage is further constricted by placing a bar screen in it. The bar screen is essential and is usually required by plumbing codes, but the unobstucted cross-sectional area of the outlet should be greater than the cross-section of the drain pipe called for in Sec. 129, so as to insure quick emptying of the tub and a thorough flushing of the drain pipe.

The waste may be controlled by a plug and chain, which is workable and economical, or by some sort of remote-control

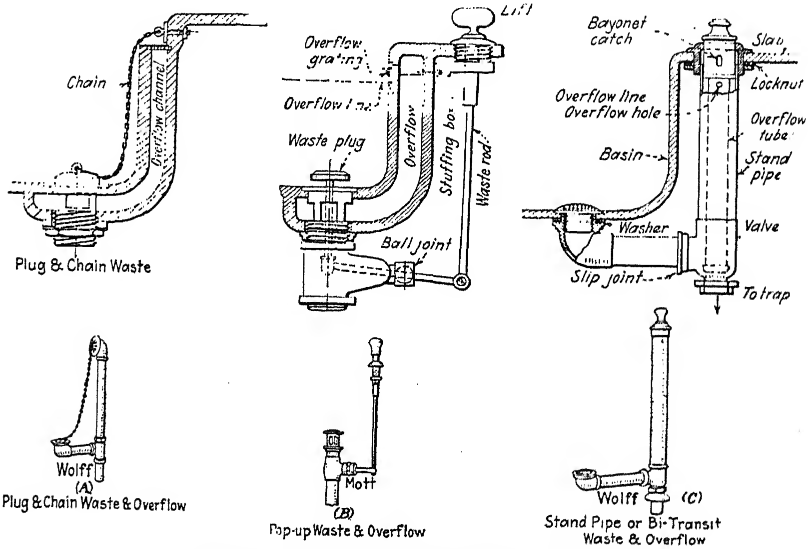


FIG. 143.—Wastes and overflows for bathtubs and lavatories.

valve. An objection to the plug and chain arrangement is the liability of their being torn apart resulting in loss of the plug or difficulty in removing it. The chain is difficult to clean and is usually quite foul. Types of remote-control wastes are shown in Fig. 143. The standing overflow and waste, or by-transit waste, is illustrated in Fig. 143C. In this type the standpipe is placed in position within an enclosure and is raised and lowered mechanically. In such an installation the standpipe should be easily removable for cleaning. The objection to this arrangement is the large area which is fouled and which probably will not always be cleaned after each bath, but the obstruction to the use of the tub which is offered by the standing waste is overcome.

An overflow pipe should be provided as a safety measure to prevent the flooding of the building if the water is turned on too long. This overflow should be protected with a strainer in the same manner as is specified for the waste pipe. Among the common faults met with in overflow pipes is that they are too small to carry water away as fast as it will come in and the infrequent use of the overflow results in fouling of the interior of the pipe which is conducive to clogging or leakiness or both without quick discovery. Great care should be taken to connect an overflow pipe to the drain pipe from its own fixture and to see

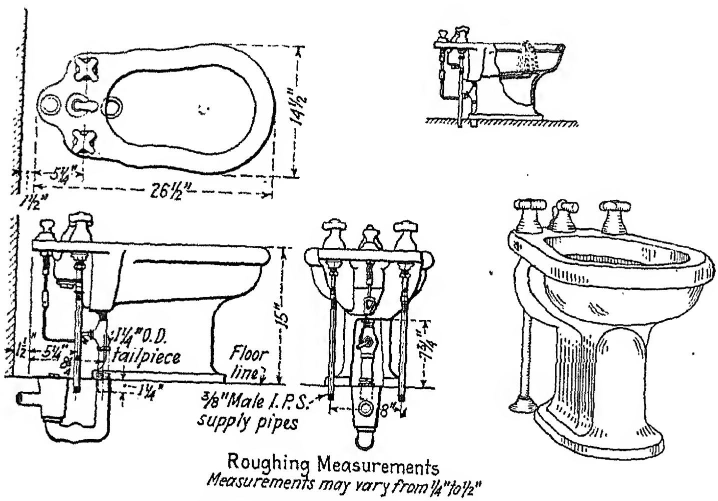


Fig. 144.—Bidet. (*Courtesy Thos. Maddock's Sons Company.*)

that this connection is *above the trap*, that is, the overflow connection must be between the trap and the fixture.

264. Sizes of Bathtubs.—The most comfortable size of bathtub is one that will permit the user to lie at full length in it. This calls for an overall length of 8 ft. or more to allow for the slope of the end or ends. Such lengths are available but are not commonly used. Practically any size of bathtub is available from an infant's tub up to lengths of 8 to 10 ft. Common inside widths are in the neighborhood of 24 in. in the clear and a maximum depth of about 18 in. The edge of the tub should be between 18 and 24 in. above the floor.

265. Special Tubs.—Special tubs for bathing various parts of the body are sometimes included in the equipment of the bath-

room. Principles similar to those applicable to the selection of a bathtub are applicable to the selection of such special tubs.

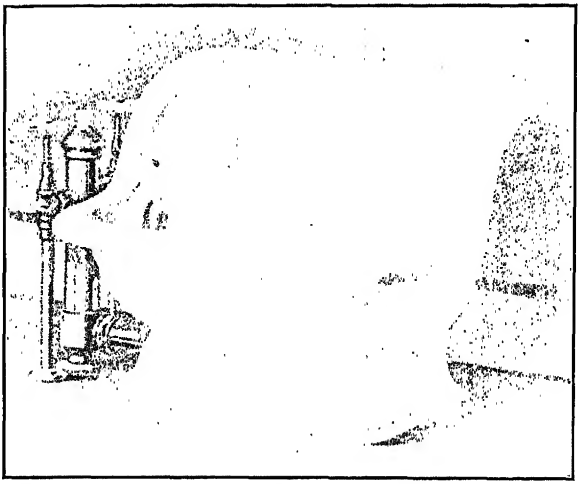


Fig. 145.—A sitz, seat, or footbath. (*Courtesy J. L. Mott Company.*)

A bidet is shown in Fig. 144, a sitz bath or foot bath in Fig. 145, a baby bathing outfit in Fig. 146, and a combination fixture in Fig. 147.

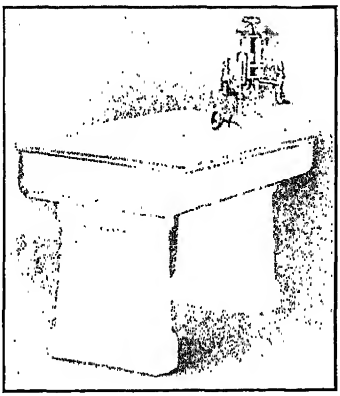


Fig. 146.—Mott standard baby bath with Leonard thermostatic temperature-control valve.

266. Hospital Tubs and Other Special Fixtures.—Bathtubs are not recommended for general use in public institutions for

many reasons. These include the danger of contagion through uncleanliness, the time necessary for filling and emptying, abuse, and in hospitals—particularly for the insane—the danger of injury to the patient when bathing without an attendant. In private hospitals, or for patients with special nurses, the bathtub may be used. The tubs may be either fixed or movable. The fixed tub should fill all of the requirements already described

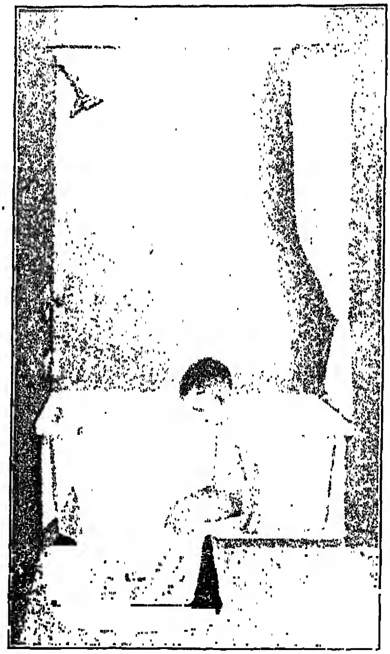


Fig. 147.—Combination bathing tub, shower bath, foot bath, bathtub, and baby bath. (*Courtesy Wheeling Sanitary Manufacturing Company.*)

for ordinary tubs and in addition it should be so located in the bathroom that the attendant can get all around it. The inlet valve and waste control are sometimes so arranged as to be controllable only by the attendant either by a key or out of the reach of the patient in the tub. The movable tub is usually made of cast iron, enamel on the inside and painted on the outside. The tub is supported on rubber-tired wheels and is provided with a long handle for pulling it about as shown in Fig. 148. It is filled from special faucets, not attached to the tub, placed over

a floor drain into which the tub is emptied through a large outlet pipe controlled by a quick-opening gate valve. Types of special fixtures used in hospitals are shown in Fig. 149.

267. Shower Baths.—The use of shower baths in gymnasiums, clubs, institutions, private homes, and other locations is extensive, and, if possible, is growing in extent and popularity. Among the outstanding advantages of the shower bath are low cost of installation, small water consumption in comparison with a bathtub, immediate availability for use without loss of time in filling and emptying, fundamental cleanliness in that clean water is sprayed continuously over the body, and the sensation of exhiliration and stimulation which results from its proper use. An objection sometimes offered by women to the use of the shower bath is the almost unavoidable wetting of the hair.

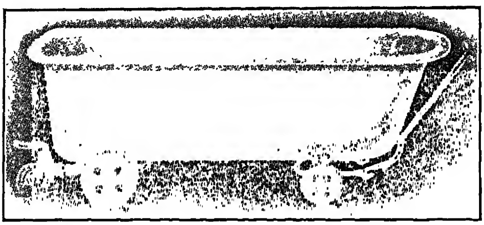


Fig. 148.—Movable bathtub. (*A. Weiskittel and Son Company.*)

268. Shower-bath Compartments.—Shower baths are installed in special compartments, as illustrated in Fig. 150, or are combined with bathtubs as shown in Fig. 130. The walls of the compartment may be of marble, slate, soapstone or other easily cleaned and non-absorbent material. Dimensions of standard slate shower stalls are shown in Fig. 202, and Table 143. They should extend all around the shower, the entrance to the compartment, if possible, not being opposite to the spray. The floor should be of tile, marble, cement, enameled iron or similar material and it should slope gently towards the drain. The slope should be very slight, not over ¼ in. per foot, because of the danger of slipping on a too steeply sloping floor. In some baths, a removable slatted wooden covering is placed on the floor to avoid the chill of the permanent and impervious floor and to overcome the danger from slipping. The valves for the control of the water supply should be within reach of the bather when

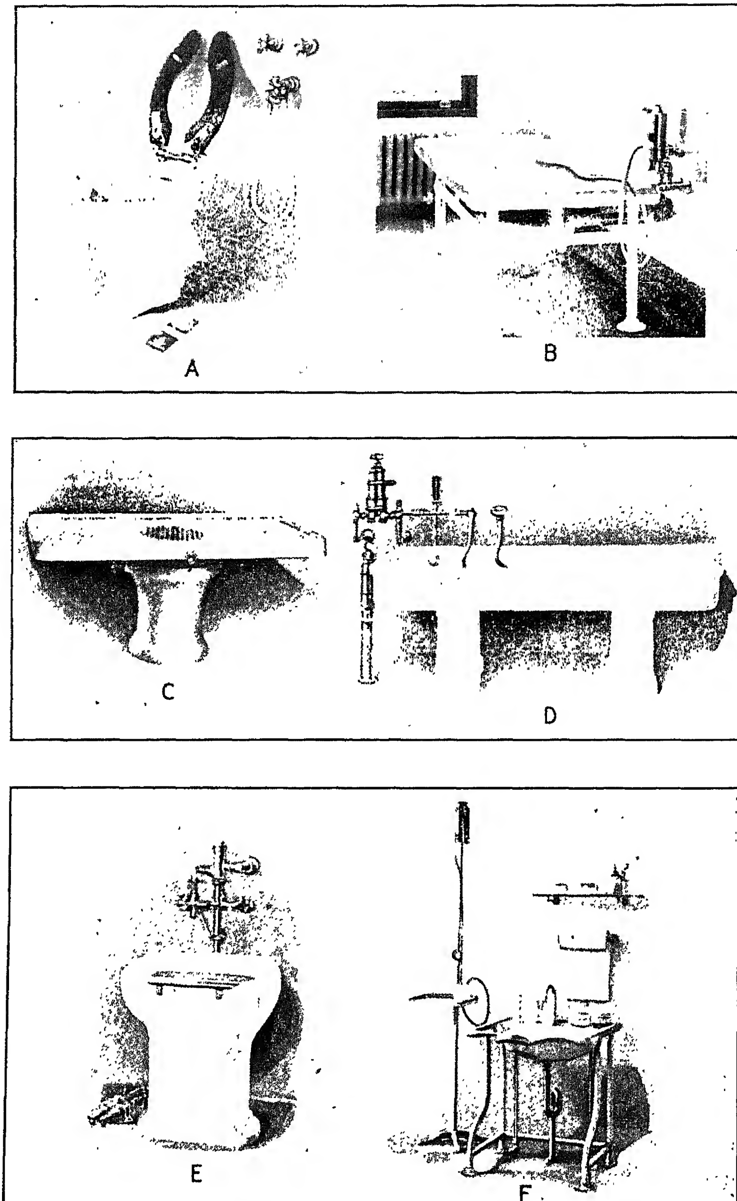


FIG. 149.—Special types of hospital fixtures. (*Courtesy J. L. Mott Company.*)

under the shower, except in special cases in hospitals and public institutions. A floor drain for a shower bath is illustrated in Fig. 151.

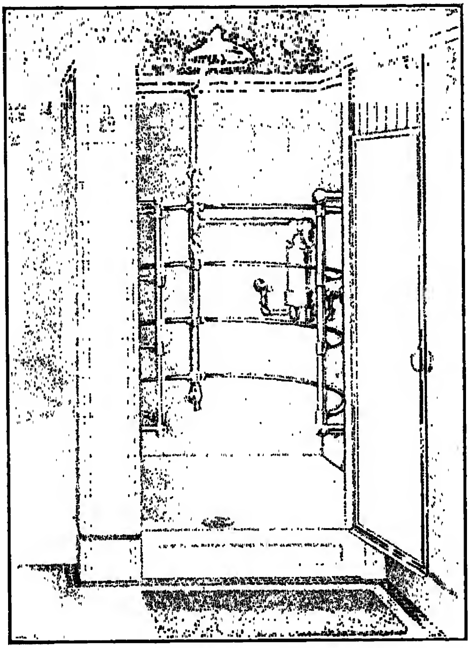


FIG. 150.—Combined shower-bath and needle-bath compartment with thermostatic control valve. (*Courtesy J. L. Mott Company.*)

EXPLANATION OF FIG. 149.

(A) "*Lombard-Duplex*" syphon-jet bed-pan closet with extended front and back lip and integral bed-pan lugs, top inlet, No. 8 birch-stained mahogany open front and back seat, connection to wall, slow-closing foot-action flush valve concealed in floor, regulating stop valve concealed in floor, No. 31 floor flange, D-2560 combination compression ½-in. supply valves with 5-ball metal handles, supply nozzle with hook, rubber hose, and hand spray with grip-control valve.

(B) Marble irrigation slab with waste strainer, wrought-iron pipe frame finished white enamel, B-10 "*Leonard*" thermostatic mixing valve, check valves, loose-key stop valves, ½-in. supply pipes to wall, hose connection, 5-ft. rubber hose, mercury thermometer and 1½-in. half S trap with nipple to wall.

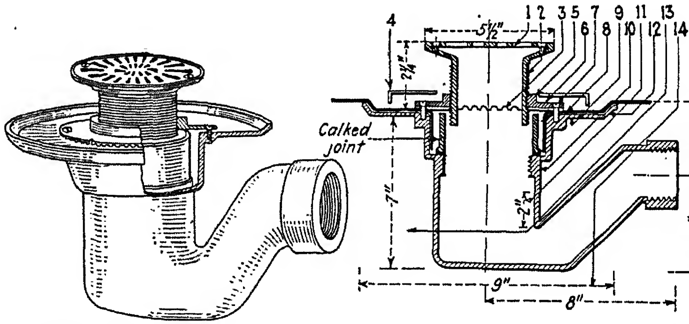
(C) "*Delano*" enameled-iron autopsy table with revolving top, spring catch, enameled inside flushing rim hopper with special full S trap, enameled-iron pedestal, cross-bar strainer, compression control valves for hot and cold water with connections to flushing rim.

(D) "*Hahneman*" Durecast roll-rim receiving bath, Durecast pedestals, standing waste, B-5 "*Leonard*" thermostatic mixing valve, check valves, loose-key stop valves, ½-in. supply pipes to wall, mixed-water supply pipe, mercury thermometer, bell supply with control valve, hose connection with control valve, rubber hose, rubber-bound spray and wall hook.

(E) "*Brandon*" vitreous china flushing-rim clinic slop sink with integral trap, bed-pan jet, combination pedal supply valve for hot and cold water to jet, "*Oscilla*" flush valve with union joint angle stop valve, 1¼-in. offset tubing flush connection and combination compression faucet with integral stop valves, pail hook, and brace and rim guard.

(F) Enameled-iron genito-urinary prophylaxis straddle stand, open-waste strainer, low gooseneck spout, foot-action supply valves with couplings.

269. Temperature Control.—The control of the temperature of the water in a shower bath is difficult and offers a serious objection to its use. The simplest and most inexpensive arrangement of piping to a shower bath is to lead cold and hot water through separate valves to a common junction, which may be an ordinary tee, and to depend on mixing the two temperatures in the pipe. No valve should be placed on the pipe between the tee and the shower head. In some installations it has been found desirable to place check valves on the supply lines close



1. Brass bar strainer N. P. Diameter 5 in. and secured to brass extension tail piece with removable brass screws.
2. Brass tail piece 2½ in. long and threaded 3-in. iron pipe size.
3. Shows the grooves on the under side of seepage plate through which the seepage drains back into trap.
5. Seepage plate tapped 3-in., connects the tail piece to trap body with a screwed joint, the seepage plate being placed over the lead pan and connected to trad body by four brass screws.
6. Recess formed in the upper portion of trap into which the lead pan is secured to trap body by a calked joint.
7. Brass screws that secure the seepage plate to trap.
8. Lead pan which is permanently secured to trap by a calked joint.
9. Cast anchor which securely holds the trap body into the cement and forms a basin for the seepage waste.
10. Threads in the upper portion of trap for securing iron plug for the rough test. The plug also prevents dirt entering trap and waste line during building construction.
11. Depth of water seal in 2-in. trap, 2 in. Depth of water seal in 3-in. trap, 3 in.
12. Ring forming basin of trap anchor.
13. Height of iron body 2-in. trap, 7 in. Height of iron body 3-in. trap 10½ in.
14. Outside diameter of flange, 9 in.

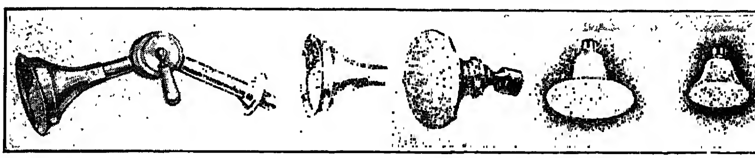
FIG. 151.—Shower bath floor drain. *(Greenwood Manufacturing Company.)* (Patented Dec. 29, 1923.)

to the tee to prevent water of one temperature from flowing into the other pipe. Where there is a long piece of pipe from the tee to the shower head it is more difficult to adjust the temperature of the water by means of the separate cold- and hot-water valves. With any piping arrangement such temperature control is sensitive to pressure variations and the use of either cold or hot water in some other part of the building may result in scalding or chilling the bather. In a battery of showers, as in a gymnasium, the temperature of the water can be controlled

manually in a supply tank, an attendant watching the temperature of the water in the tank.

Mixing valves to replace the tee are so designed that the cold-water port is always opened before and closed after the hot-water port, thus minimizing the danger of scalding. Automatic mixing valves are available with which, by the turn of a single handle, as shown in Fig. 66, the temperature of the water can be changed. Another type which is shown in the same figure, will deliver water at any desired temperature and is controlled by a thermostat.

270. Shower Heads and Sprays.—Various types of shower heads or sprays are illustrated in Fig. 152. The holes in a shower head should be large enough and of sufficient total area to prevent the building up of pressure above 20 to 25 lb. per



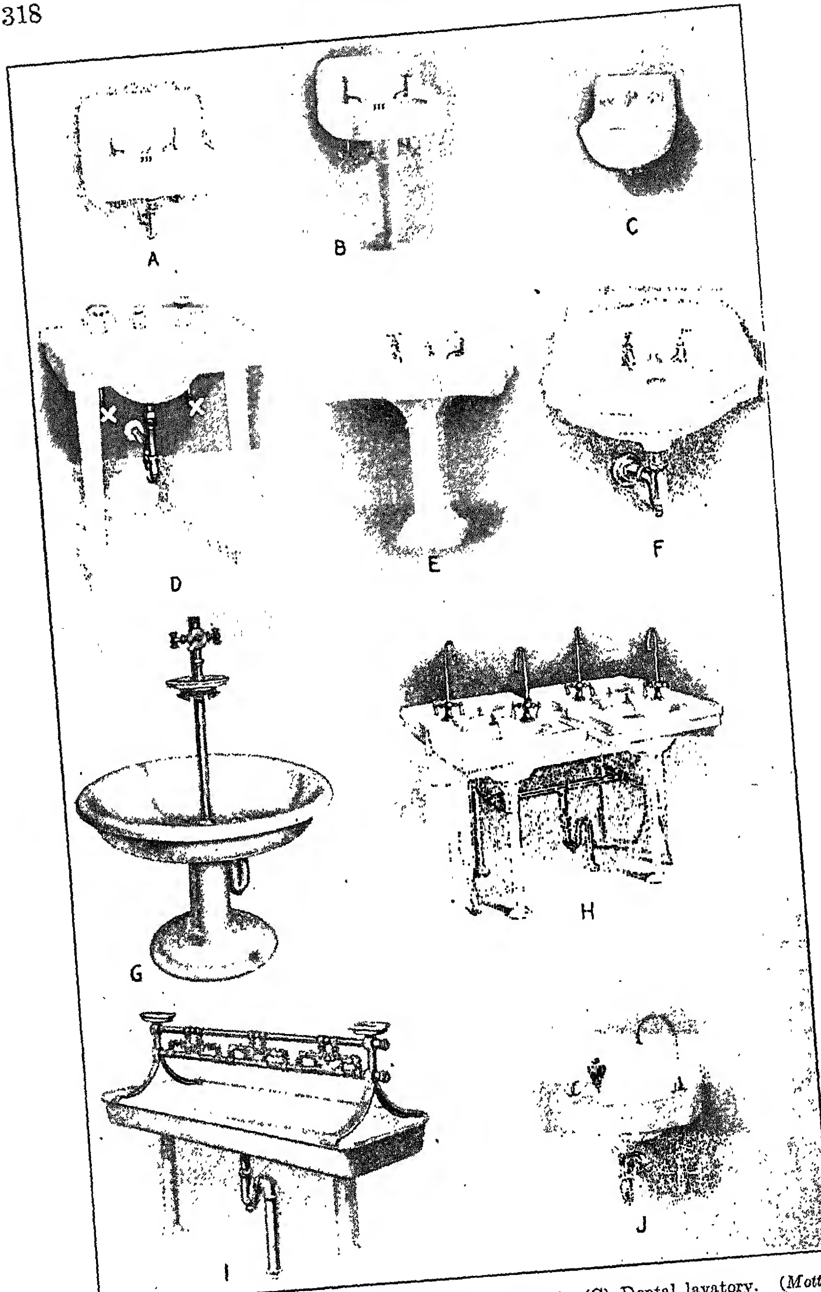
(A) Swinging joint, brass. (*Mueller.*) (B) Fixed spray, brass. (*Mueller.*) (C) Ball joint, brass. (*J. B. Wise Company.*) (D) Fixed spray, porcelain. (*Chicago Potteries Company.*)

FIG. 152.—Types of shower heads.

square inch in the spray when delivering the rated flow of water. A pressure higher than 5 to 10 lb. per square inch will be uncomfortable to the bather and a pressure much below 2 to 3 lb. per square inch may prevent a proper distribution of water in a large shower head. A shower head 4 in. in diameter with 70 holes about $\frac{1}{32}$ in. in diameter each is amply large for all ordinary requirements. Heads 6 to 8 in. in diameter are in common use.

The rate of supply of water to a shower bath should be about 20 to 35 gal. per minute. The recommended size of supply pipes to shower baths is given in Table 33, and the sizes of waste pipes is given in Table 57.

When installed to throw the spray vertically downwards and all of the holes in the spray are on the same level the shower head will sometimes become air bound and water will drip from it for many hours after it has been turned off. This can be overcome by placing an air inlet in the head so as to admit air above the trapped water.



(A) Wall type. (Kohler.) (B) Single leg. (Kohler.) (C) Dental lavatory. (Mott.) (D) Two legs. [illegible] *Specialty Company.*) (E) Pedestal. (*Richmond* [illegible] *Company.*) [illegible] (*Sanitary* [illegible] *Radiator Company.*) [illegible] [illegible]*pany.*) (G) Circular lavator[illegible] [illegible] (*Ebinger* [illegible] [illegible]pe. O[illegible] (J) (H) Factory type. [illegible] Surgical lavatory. [illegible]

Shower-bath heads can be installed so that they do not wet the bather's hair. Needle baths and special types of spray baths can be installed to avoid wetting or to concentrate water on any part of the body. They are, therefore, very useful in certain treatments in hospitals.

271. Lavatories or Wash Basins.—The materials best suited for the construction of lavatories are vitrified porcelain, china, glazed earthenware, and enameled iron. Metal is also used and when properly designed is satisfactory. Its use is confined mainly to factories, theaters, jails, and other places where rough usage is anticipated, or in situations subject to vibration as in railway cars. The lavatory should be made of one piece including the bowl and the table surrounding it. A lavatory consisting of a separate basin and table will not stand rough usage and the joint between the table and the basin is difficult to maintain and will result in leakage and insanitary conditions.

The desirable features to be noted in the selection of a lavatory or wash basin are ease in cleaning, absence of cabinet work, durability, economy, and attractive appearance. Various types of lavatories are shown in Fig. 153. The bowl is usually oval in shape with a steep slope to the bottom and with the waste in the center or towards the rear. The bowl has a capacity of about 1 gal. up to the overflow. The waste opening should have as large capacity as the waste pipe and should be protected by a heavy strainer. Strainers usually consist of two metal bars about 1/8 to 3/16 in. thick, crossing at right angles. The net open area between the bars should slightly exceed the cross-sectional area of the waste pipe. The basin should empty quickly, acting as a flush tank for its own trap and waste pipe. It should be self-cleansing, should not contain invisible fouling surfaces, and should be simple in appearance, operation, and maintenance.

272. Water Supply to Lavatories.—Faucets for supplying water to basins are discussed in Chap. V. The cold-water faucet should be placed on the user's right. In hospital operating rooms and in other situations it may not be desirable to touch either the faucet or the waste with the hands. A foot- or knee-controlled faucet is shown in Fig. 153J. In hotels of the cheaper type, office buildings, jails, and other locations, self-closing faucets are sometimes installed to prevent the waste of water. The use of self-closing faucets on lavatories in hotels is undesirable because these fixtures are sometimes used for other purposes than washing, and

a self-closing faucet will force the user to wash in water standing in the basin. The amount of water used in washing in running water is frequently less than that used when the basin is filled with water. The use of self-closing faucets will, however, cut down the water consumption. Valves placed on the water supply pipes near the lavatory are convenient when it is necessary to make repairs to the faucets. In the selection of faucets and wastes it is desirable that the lavatory be kept as free as possible from obstruction. The faucet should, therefore, not project far into the basin.

273. Setting of Lavatories.—The lavatory may be set at any convenient point against the wall, in a corner, or in a compartment. If placed in a compartment or closet ventilation should

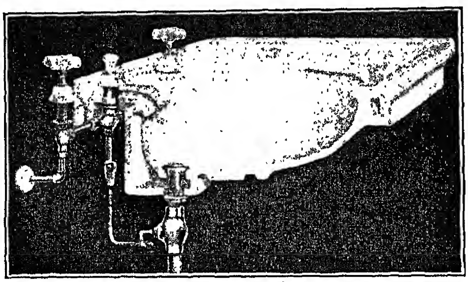


Fig. 154.—Section through a lavatory showing a pop-up waste (*The Sanitary Earthenware Specialty Company.*)

be provided. The top of the lavatory should be placed about 30 in. above the floor. Where legs or brackets are used to support the lavatory they should be made adjustable so as to fit the roughing-in work.

274. Waste and Overflow.—Waste controls and overflow arrangements are similar to those used in bathtubs and are subject to the same objectionable and commendable features as are discussed in Sec. 263, except that the standing waste cannot be used in the center of the bowl and any obstruction to the free use of the bowl is more objectionable than a similar obstruction in a bathtub. Various types of waste control are illustrated in Figs. 143, 153, and 154. An admirable waste to occupy little space is the pop-up waste shown in Figs. 143B and 154.

275. Trap and Waste Pipe.—The trap and waste pipe should be simple and attractive in appearance and should be placed as close as possible to the basin. Wherever possible the waste

pipe should pass through the wall at the back of the lavatory rather than to extend through the floor beneath it. All pipes should be completely exposed. Cabinet work, curtains, or any other obstruction to complete exposure should not be tolerated. The connection between the trap and the waste pipe from the basin should be made by means of a slip joint to allow for the slight movements and vibrations which are inevitable to the use of the basin. The trap should be supported by the waste pipe from the wall. Types of traps used for all fixtures, including lavatories, are discussed in Chap. VIII. The sizes of waste pipes are given in Sec. 129, and the sizes of supply pipes in Chap. IV. It is permissible, and is considered good practice, where a number of lavatories are to be set in battery, to permit them to discharge into a common waste pipe with one trap for a number of lavatories, as illustrated in Fig. 112. The limiting number of fixtures which may be attached to one trap is a matter of judgment. The undesirable feature of the arrangement is the length of untrapped waste pipe exposed to foul the air of the room.

276. Kitchen Sinks.—The kitchen sink is among the most useful of the plumbing fixtures in the household. In country homes, only partially equipped with plumbing, the kitchen sink is sometimes the only fixture installed. In the selection of any sink the desirable features set forth in Sec. 271, for a lavatory, are equally applicable. Special attention should be paid to the location of the kitchen sink because of the amount of time spent at it by the women of the household. It should be placed beneath a window or where the light from a window will fall directly on it. Artificial illumination should also be considered. It is not satisfactory to illuminate a kitchen with a single central light as the shadow of the user will fall upon the work in the sink when the sink is placed against the wall. In hotels and institutions kitchen sinks are sometimes placed in the center of the room where they are accessible from either side.

277. Height of Sink above the Floor.—The height of the kitchen sink above the floor is an important consideration for the comfort of the user but difficult of proper attainment because of the diversity of height of users. A fault from which it is difficult to shake the plumber, the architect, and the manufacturer is the placing of the kitchen sink too low. The sink should be at such a height that anyone washing dishes therein need not bend over. It is more comfortable to raise the hands slightly than to

bend over for a long time. A short person can stand on a board to reach the high sink but a tall person must stoop to reach a low sink. For these reasons there is more danger of getting the sink too low than too high. In general, the distance from the floor to the bottom of the sink should not be less than 30 in. and preferably higher.

The proper height of a sink is the height at which the individual woman can work most comfortably and efficiently. There can be no *standard* heights for sinks until there is a *standard* height and build for all women.*

The depth of a kitchen sink is about 6 in.

The table or apron on the side of the sink, as shown in Fig. 155, should be not less than 36 in. above the floor, and preferably higher. Where legs or brackets are used to support the sink they should be made adjustable so as to fit the roughing-in work.

278. Materials for Kitchen Sinks.—The principal materials in present-day use for kitchen sinks are enameled iron, earthenware, cast iron, slate, soapstone, copper, and metal lined with zinc. Recommendations of the Division of Simplified Practice of the U. S. Department of Commerce, concerning slate sinks are given in Sec. 18, of Appendix I. Standard dimensions of slate sinks are given in Figs. 198 to 201, and Tables 138 to 142. Enameled iron is the more desirable material, particularly for household use, because of its attractive appearance. Other materials than enameled iron are sometimes used in hotels, restaurants, and institutions because of their durability and lower first cost and their ability not to show stains. They are usually more difficult to keep clean, however. Soapstone, slate, earthenware, or lead-lined metal sinks are used almost exclusively in chemical laboratories because of their greater resistance to corrosion.

279. Types of Kitchen Sinks.—Various types of kitchen sinks are illustrated in Fig. 155. It is to be noted that a corrugated table or drain board made of impervious material is placed on one or both sides of the sink. A back or splash plate of the same material is also essential in a complete kitchen sink installation where the sink is placed against the wall. Where the drain board is to be placed only on one side of the sink it should be placed on the right of the user. Many installations have them on

* From an advertisement of the U. S. Sanitary Manufacturing Company.

the left side which is less convenient for a right-handed person. Neither the sink nor the drain board should be placed in a corner if another convenient location can be found. The drain board on the right makes it convenient for a right-handed person to remove dishes from the pan and place them in the drainer with

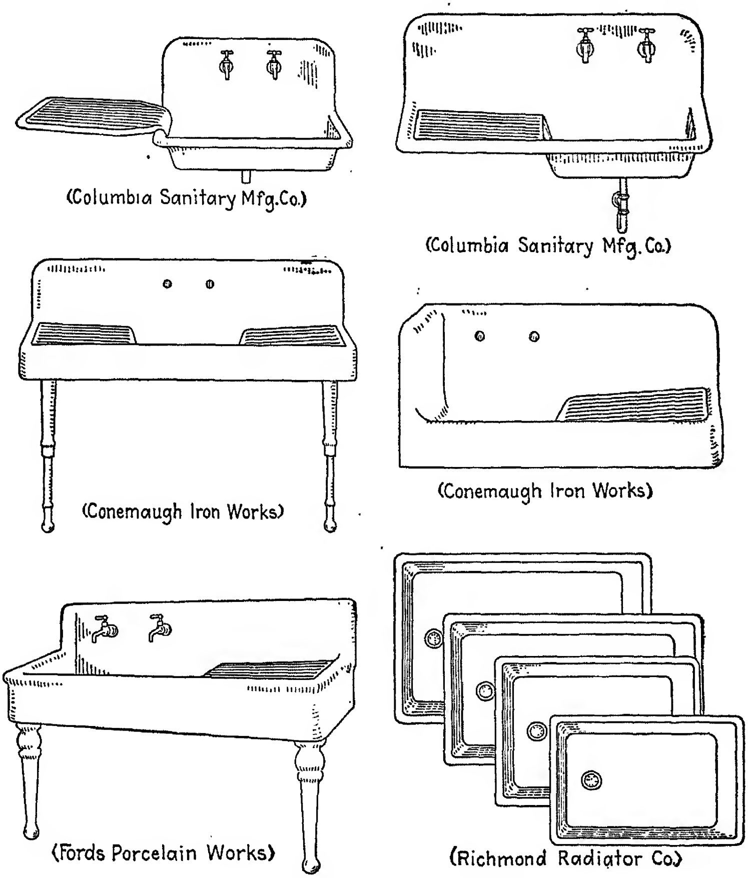


FIG. 155.—Types of kitchen sinks.

the right hand. A drain board placed in a corner is undesirable because it forces the dish wiper to step or reach around the dish washer in order to reach the dishes.

Kitchen sinks can be obtained in almost any size up to 24 by 120 in. or even larger. Most sinks are manufactured with a depth

of about 6 in. A convenient size for a single family residence is about 20 by 30 in.

280. Water Supply to Kitchen Sinks.—Water is usually supplied to kitchen sinks through two separate faucets with the cold-water faucet on the right. The custom of supplying a threaded end on the cold-water-supply faucet for the use of a hose connection is falling into disuse. Combination or mixing faucets which supply either hot or cold water from the same nozzle, the nozzle being arranged to swing in a horizontal plane across the top of the sink, as shown in Fig. 66, are sometimes used on kitchen sinks. Sizes of water-supply pipes are given in Table 34, page 63.

280*a*. Waste Pipes and Traps from Kitchen Sinks.—The waste from any sink should be protected by a perforated strainer the top of which is flush with the bottom of the sink, thus giving a smooth bottom surface. This strainer should be removable for cleaning and to give access to the trap. It should fit snugly into its recess and should be fastened there securely. The holes should be about 1/8 to 1/4 in. in diameter and there should be sufficient area to the holes to assure the quick drainage of the sink and flushing of the drain pipes. The total area of the holes should be slightly greater than the cross-sectional area of the waste pipe. This will require about 150 1/8-in. holes, 70 3/16-in. holes, or 36 1/4-in. holes. The strainer plate may be made of brass or enameled iron. Sizes of waste pipes from kitchen sinks are given in Table 57, page 159.

The trap should be placed as close to the sink as possible to avoid exposing soiled pipe surfaces to the air of the room and to avoid the blows to which a low-hung trap is likely to be subjected. The drain pipe should pass through the wall well above the floor and behind the sink, for the same reason. The connection between the sink waste and the trap should be made with a slip joint, unless a lead trap is used, to allow for vibration and movement of the fixture. All piping beneath the sink should be completely exposed to view without protective cabinet work or other shield whatsoever. This is essential to the maintenance of cleanliness, the suppression of odors and vermin, and correct maintenance of the fixture.

281. Pantry Sinks.—A pantry sink is illustrated in Fig. 156, and a high goose-neck faucet in Fig. 66. Such sinks are used principally for cleaning silverware, cut glass, and china, and for drawing water for table use. These sinks are usually made of

copper because breakable articles are less subject to fracture than in a sink of enameled iron, soapstone, porcelain, or similar hard material. As a rule, too much wood is used in the construction of the sink to assure immaculate cleanliness, and it is difficult to keep the joint between the metal and the wood free from filth. High goose-neck faucets are usually used in these sinks so that a pitcher can be placed under them for filling.

The drain pipe should be 1¼ in. in diameter and each water supply pipe not less than ⅜ in. Otherwise, the principles and considerations applicable to kitchen sinks are applicable to the selection and installation of pantry sinks.

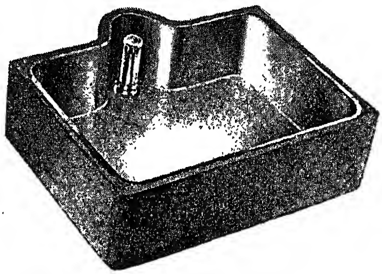


FIG. 156.—A copper pantry sink encased in wood. (*Mott.*)

282. Slop Sinks and Sinks for Special Purposes.—Slop sinks, such as are illustrated in Fig. 157, are used for drawing water for scrubbing and cleaning and to receive contents of scrub buckets and vessels containing slops. They are advantageous in saving wear and tear on bathtubs and toilets. They are sometimes more convenient than such fixtures, and they are indispensible in hotels, hospitals, and institutions.

The size of a slop sink should be about 20 to 24 in. square and 10 to 12 in. deep. The edge of the sink should be placed about 24 in. above the floor to avoid lifting of heavy vessels. The amount of time spent at the sink is usually short so that the effect of bending over the sink is not noticeable.

The water-supply and drainage equipment for slop sinks is similar to that for kitchen sinks and in addition provision is sometimes made for flushing them as for a water closet or urinal. Flushed slop sinks of the type shown in Figs. 149A and 157 are particularly useful in hospitals. The hose shown in Fig. 149A is used primarily for cleansing bed pans and may be used to aid in flushing the sink.

283. Laundry Trays or Washtubs.—Laundry trays are plumbing fixtures used for the washing of clothing. They are made of slate, earthenware, soapstone, enameled iron, or porcelain. Recommendations of the Division of Simplified Practice of the U. S. Department of Commerce concerning slate trays are given in Sec. 18, of Appendix 1. The use of any of these materials will give satisfactory results, porcelain being the most expensive

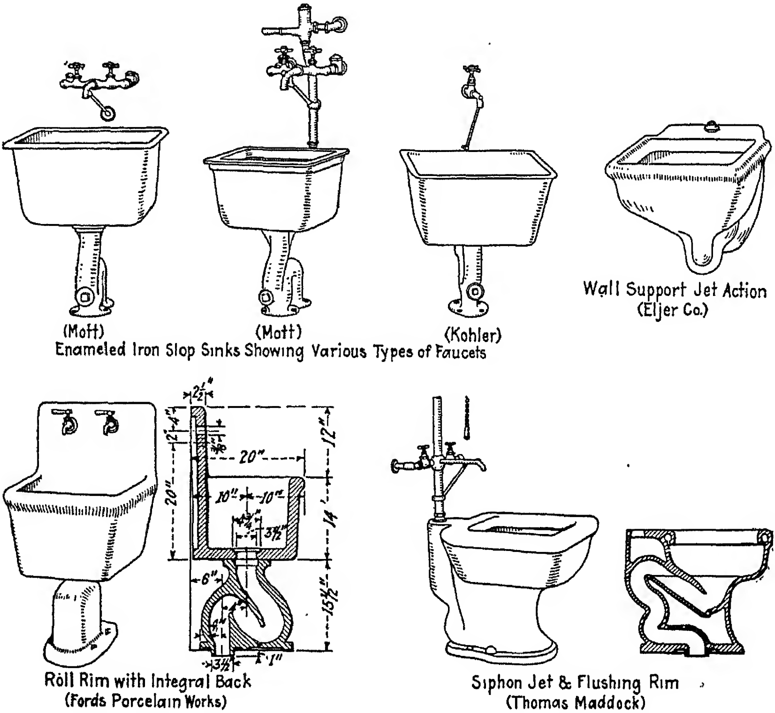
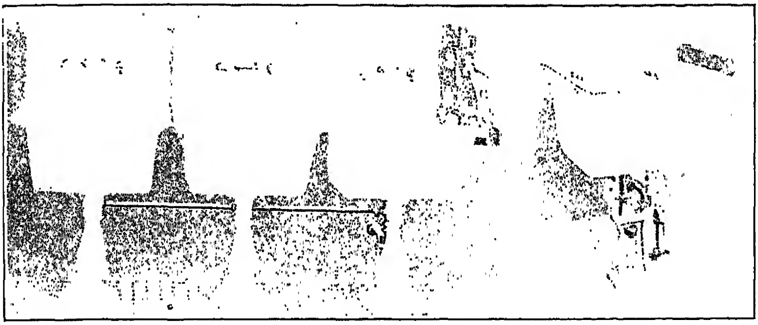


FIG. 157.—Types of slop sinks.

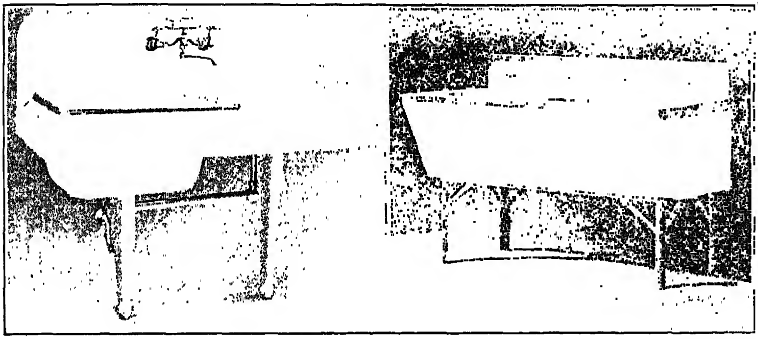
and infrequently used. Laundry trays are more generally standardized than other plumbing fixtures and there is less variety from which to choose. Typical laundry tray installations are shown in Fig. 158.

In the selection of a laundry tray, sanitation, cleanliness, water tightness, and ease in maintenance are assured by the choice of a tub of white or light-colored glazed material made in one piece with curves instead of angles at the corners. The

fixture should drain quickly and should act as a flush tank for the drain pipes. Comfort in use is obtained by selecting a fixture of proper size and installing it in a proper manner. Dimensions of the inside of wash trays which have been found to be satisfactory and are generally available are: width, 20 in.; distance from front to back at top, 18 in. and at the bottom 12



Triple combination, enameled iron. (*Kohler.*) Single tray with adjustable legs. (*Richmond Radiator Works.*)



Laundry tray and kitchen sink combination, enameled iron. Tray overflows into sink. Adjustable legs. Swinging combination faucet. (*Kohler.*) Two-tray combination with integral back, stoneware. (*Chas. Wesley.*)

FIG. 158.—Types of laundry trays.

in.; and depth, 14 in. The height of the tray above the floor should be between 30 and 36 in. Standard dimensions for slate laundry trays are shown in Figs. 197 and 198, and in Tables 137 to 139, inc. The trays are usually supported on legs and these should be adjustable in length so as to make the setting of the fixture easier. It is better to set the fixture too high than too

low as a short person can place a step in front of the tray if it is too high but if it is too low a tall person must bend uncomfortably.

Laundry trays should be located in well-illuminated, ventilated, and heated rooms as an inducement to thorough and cleanly work and to assure the comfort of the user. A cover is sometimes provided for laundry trays which is used as a table when the tray is not in use for washing. The cover may be of wood, enameled iron, or other impervious material. The use of wood is not recommended. The entire cover should be detachable or all parts should be readily accessible for cleaning purposes. Laundry trays are usually installed in sets of two or three, as shown in Fig. 158. Provision should be made for the attachment of a clothes wringer to the trays in such a manner as to give security without injury to the tray. This may be done by bolting or clamping a piece of wood to the tray and attaching the wringer to the wood.

Groups of two or three laundry trays may discharge through the same drain pipe and trap in the manner illustrated in Fig. 113. A larger number of trays discharging through a single trap would leave an undesirable amount of untrapped waste pipe exposed to the air of the room. A fixture which is popular in small apartments and for crowded installations or for light laundry work, such as for baby clothes, finery, etc., is the combination laundry tray and sink shown in Fig. 158.

In this installation the cover to the tray is used as a drain board to the sink. The single trap, which may be used for this combination fixture, should be placed near the sink so as to leave as small a surface as possible exposed to the fouler wastes. Where laundry trays are placed within the kitchen of apartment buildings, or each apartment has independent laundry trays, it is possible that such trays may not be used for long periods of time. The waste pipe from the tray should, therefore, discharge through the trap under the kitchen sink. Where no sink or other frequently used fixture is available the laundry trays should not be installed

Water is usually admitted to the laundry tray through two faucets; one, on the right of the user, for cold water and the other for hot water. These are placed close up to the side of the tray, as shown in Fig. 66. They are usually made of brass, either plain or nickel plated.

The bottom of the tray is flat and slopes gently towards the waste outlet. The outlet should be protected by a screen or two crossed bars similar to that described in Sec. 271. The net area of the openings should be greater than the cross-sectional area of the drain pipe. The waste is almost invariably closed with a plug-and-chain arrangement. Overflows are not usually used on wash trays, but the sink and tray combination shown in Fig. 158 includes an overflow for the tray. Sizes of water-supply pipes are given in Table 34, page 63; types of faucets are discussed in Chap. V, and sizes of traps and drain pipes are discussed in Table 57, page 159.

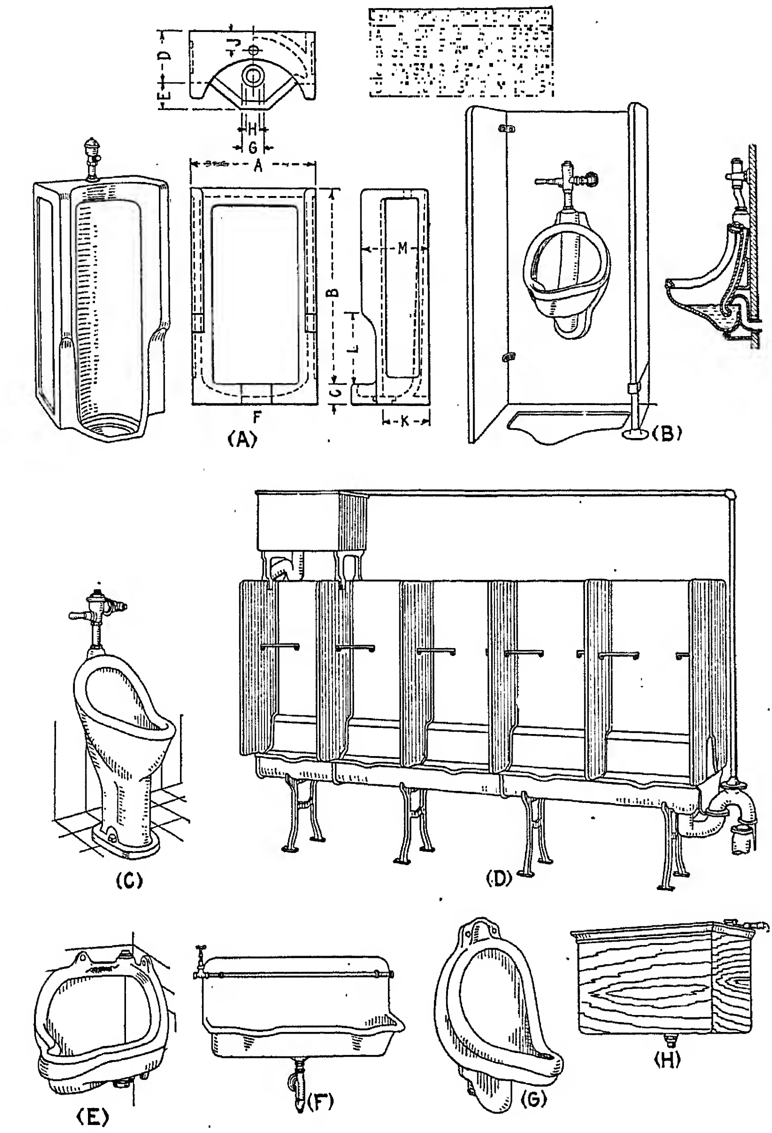
CHAPTER XVII

MISCELLANEOUS FIXTURES AND APPURTENANCES

284. Types of Urinals.—Urinals are used almost exclusively in men's toilet rooms. They are of various types such as the flat-back or wall type shown in Fig. 159B, the stall urinal shown in Fig. 159A, the pedestal urinal shown in Fig. 159C and the urinal trough shown in Figs. 159D and 159F. The height of the bowl of fixtures above the floor should not be greater than 20 to 25 in. Standard slate urinal stalls are shown in Fig. 203 and are described in Table 145. Stalls for urinals should be at least 30 in. wide and urinals placed in battery should not be closer than 30 in. on centers. There are many examples of each of these types of urinals on the market and a wide choice is offered the purchaser.

285. Materials for Urinals.—The material selected should be durable, non-corrodible, and it should have a hard glazed surface. The fixture should be constructed in one piece without crack, joint, or recess. Vitreous ware, earthenware, or enameled iron fulfil these requirements. Enameled iron is not recommended as it does not stand the abuse such fixtures often receive, and it will crack, chip or craze. Stall urinals are made of solid porcelain and vitreous china is used for pedestal and wall-hung urinals. Marble, slate, soapstone, etc. should not be used in the fixture as they are slightly absorbent and the fixture cannot be constructed in one piece. These materials can be used for the walls of stalls separating urinals. Porcelain is not altogether satisfactory for urinals as it is likely to chip or craze. Recommendations of the Division of Simplified Practice of the U. S. Department of Commerce concerning slate to be used in connection with urinals are given in Sec. 18 of Appendix I. Material which does not fulfill the requirements should not be used for urinals.

The side walls and the back of urinal stalls should be made of hard, durable, impervious material. For this purpose slate, soapstone, and marble are used and are found satisfactory. The floor under the urinal should be covered with an impervious material, it should be provided with a drain, and provision for



(A) Stall urinal. (*Woodbridge Ceramic Company.*)
(B) Wall urinal showing two types of stall walls. (*Mott.*)
(C) Pedestal urinal with flush valve and siphon jet. (*Trenton Potteries Company.*)
(D) Trough urinal with stalls. (*Mott.*)
(E) Corner urinal, wall type. (*Trenton Potteries Company.*)
(F) Trough urinal. (*Kohler.*)
(G) Wall urinal with integral trap. (*Camden Pottery Company.*)
(H) Automatic flushing tank. (*Becker Manufacturing Company.*)

FIG. 159.—Types of urinals.

flushing the floor should also be made. There is probably no fixture which disseminates more odors than an improperly installed and maintained urinal. These fixtures are universally abused; urine is slopped over the sides and on the floor; cigars, cigarettes, and matches are thrown into the bowls; and the floor is expectorated on. It is essential, therefore, that special care and attention be given to the selection and maintenance of these fixtures.

Some urinals are provided with traps included within the fixture. These are known as integral traps, one type of which is illustrated in the pedestal urinal in Fig. 159C and the wall urinal in Fig. 159G. These are designed to operate similarly to a water closet so that the trap will be emptied by self-siphonage and the seal will be restored by the last water of the flush and the refilling of the flushing tank. A local vent installed just above the trap, or immediately below the strainer, is helpful in keeping down odors only where a forced draft is provided through the vent. It is desirable that the urinal be so designed that water is retained in the bowl or beneath the strainer so as immediately to dilute urine which may fall into it. For this purpose, and to assure thorough flushing, urinals are sometimes equipped with siphon or siphon-jet traps similar to those used for water closets.

286. The Stall Urinal.—The stall urinal shown in Fig. 159A is a very satisfactory fixture. This fixture should be set with the base below the floor level so that it may act as a drain for the floor nearby. These urinals are usually not equipped with an integral trap. The trap used should be placed as near as possible to the fixture; it should be accessible and should be provided with a clean-out plug, preferably made of brass.

287. The Urinal Trough.—The urinal trough, shown in Figs. 159D and 159F is so unsatisfactory as to be used only in the most inexpensive installations. Urinal troughs can be kept clean and odorless, however, by the exercise of care in maintenance, but the joint between the fixture and the wall presents an unavoidably objectionable feature.

288. Flushing of Urinals.—Flushing of urinals should be provided for either automatically or by a hand-pull chain, a flushing valve, or other manual device. Manually operated flushing devices on urinals are not recommended because of the natural reluctance of the public to use them, for sanitary reasons. The volume of each flush should be in the neighborhood of 2 gal., and the capacity of the flush tank should be about 3 gal. In

automatic types of flushing devices the frequency of flush should depend upon the frequency of use. The period between flushes is adjusted by means of the supply valve to the overhead flush tank. The supply is arranged so as to fill the tank once in 5, 10, or 15 min., as desired.

An automatic flush tank is illustrated in Fig. 160. It operates as follows: the supply valve is opened sufficiently to fill the tank in the desired time between flushes; the rising water level raises the float *B* and with it the arm of the flush pipe which is pivoted about point *A*. When the float has raised to the flushing level of the tank the arm stops rising and the float is filled with water and sinks. Water rushes down the flush pipe to the urinal and siphonic action drains the water from the float through the small pipe *C*. When the float and tank are emptied of water the cycle of operations has been completed and a new cycle is ready to begin.

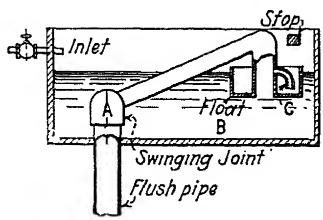


FIG. 160.—Automatic urinal flush tank.

The flush pipe from the tank to the urinal should be about ¾ in. in diameter. It may be made of brass or nickel-plated brass tubing. The urinal bowl should be provided with a flushing rim to distribute the water in the bowl. Stall urinals with floor outlets should be so equipped as to have the entire vertical wall as well as the floor bowl of the fixture throughly flushed. The flushing water is distributed over the walls of the fixture as a fan-shaped spray. Trough urinals are usually flushed by means of a perforated pipe placed along the back of the trough.

The outlet or waste from the fixture should be protected by a perforated brass, nickel-plated brass, or enameled iron strainer, or five or six holes about ¼ in. in diameter may pass directly through the material of the fixture to serve as an outlet. Some urinals are equipped with an overflow waste cast into the fixture. The purpose of this is to prevent spilling from the fixture in case of the stoppage of the drain pipe. Each urinal should be separately trapped.

The water-supply pipe to the flush tank should not be less than ⅜ in. in diameter and the drain pipe and trap should be 2 in. in diameter.

289. Safes.—Safes are drip pans or drains placed beneath pipes or fixtures to collect and drain off any leakage or dripping which may escape from them. Protection is thus afforded to walls and ceilings. The waste pipe from a safe should be generous in size sufficient to carry off the full discharge from the water-supply pipe to the fixture which is protected by the safe. As the waste pipe is very seldom used it should not be connected to the plumbing system and need not be trapped as no water seal could be maintained in it. It should discharge, through an open connection, into another plumbing fixture or into a floor drain. Safe-waste pans are made of sheet zinc, copper, or lead. These pans are 2 or 3 in. deep and of a sufficient size and shape to serve the purpose desired. In present-day open plumbing, safes are seldom used under plumbing fixtures except under attic tanks and in other out-of-the way places where overflows or leakage will not be quickly discovered, or where the ceiling or wall decorations underneath are unusually expensive or difficult to renew.

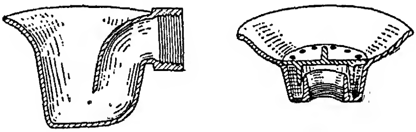


FIG. 161.—Refrigerator drains. (*Bignall Company.*)

Safes may be used also under cold-water supply pipes on which moisture may condense from the atmosphere, a phenomenon known as sweating of the pipe. The most common place for the installation of safes is under iceboxes. A detail of a refrigerator safe or drain is illustrated in Fig. 161; various permissible piping arrangements are illustrated in Fig. 113; and detailed specifications concerning trapping, venting, and discharge of safe waste pipes are given in Sec. 141.

290. Floor Drains.—Floor drains are used to drain off water which may collect on the floor. They are useful principally on impervious floors and in dwellings they are placed in cellars, bathrooms, laundries, kitchens and other locations where water may accumulate on the floor. Types of floor drains are illustrated in Fig. 162, and a floor drain connection is shown in Fig. 111. Floor drains should be placed in a depression in the floor towards which the entire floor slopes. The top of the strainer should form the bottom of the depression in the floor. The

drains should be of heavy, durable construction, preferably of cast iron throughout, or cast iron with brass or nickel-plated brass cover. The strainer should consist of a hinged or removable cover perforated with holes ¼ to 3/16 in. in diameter and slightly greater in total area than the cross-sectional area of the

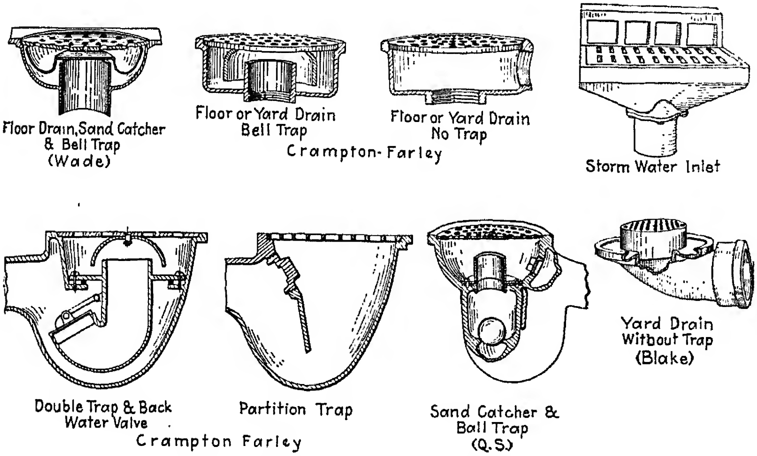


FIG. 162.—Types of floor and yard drains.

drain pipe. The drain pipe should be 2 in. in diameter for cellar floors and never less than 1¼ in. in diameter.

The drain pipe on floor drains located in dry cellars or other locations subject to infrequent floodings should discharge into other drain pipes not used nor likely to be used for the convey-

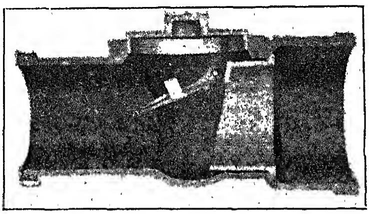


FIG. 163.—Back-water valve for drain.

ance of sewage. Where the sanitary sewer or a combined sewer offers the only drainage outlet it may be used for this purpose. In this case the floor drain waste pipe should be trapped with a deep seal trap with large water capacity and some clear water drain, such as an ice box drain, tank overflow, or hydrant drip,

should be discharged into it. A back-water valve, as shown in Fig. 163, may be placed in the line to prevent water from the sewer from flowing backwards through the drain. Floor drains located above the ground floor should discharge, untrapped, into drains on lower floors, as suggested for safe-waste pipes, and finally into a drain with a permanent water seal.

Floor drains on upper floors are sometimes equipped with gate valves and water-sealed traps, and are connected to the pipes of the plumbing system. It is expected that the valves will be opened only for brief periods of time. Such an arrangement is not recommended, however, because of the probability of neglect in the closing of the valve and the evaporation of the water seal in the trap.

291. Yard and Area Drains.—Yard and area drains are similar to floor drains except that they should be more substantial in construction and should have a greater capacity for draining off water. The construction must be substantial and the foundation laid deep not only to resist the shocks of passing vehicles but more particularly to resist the heaving action of frost. Types of yard drains are illustrated in Fig. 162. They are made of cast iron, the cover being perforated for the admission of water and the exclusion of debris. If possible, they should not discharge into any drains carrying sewage and under such conditions no trap is necessary. Where they must discharge into a sewer, however, they should be trapped with a deep-seal trap of generous water capacity and some clear-water waste, such as a garden hose hydrant drip, icebox drain, etc., should be led into the trap. The trap should be located within a building or beneath the frost line to protect it against frost. It is desirable also to install a sand trap or catch basin beneath the strainer.

The outlet pipes from yard drains should be 3 or 4 in. in diameter. The location of the drains and the number to be used must be left to the judgment of the designer, but a method of estimating the amount of water flowing to the drain is presented in Sec. 190.

292. Catch Basins.—Catch basins are used for removing sand, cinders, leaves, and other material which would otherwise enter and might clog drain pipes. Catch basins are also used to prevent the entrance into a drain pipe of gasoline, oil, or grease. Special construction is required for the particular purpose of the catch basin.

Catch basins for the detention of detritus should be used under yard drains and roof leaders from which detritus may be washed. The construction of such a basins is shown in Fig. 164. The incoming water drops its detritus in the basin and the water flows out through the outlet free from such clogging material. The basin may or may not be trapped, as indicated in dotted lines in the figure. When connected to a sewer it should be trapped and the outlet opening should be at least 6 in. below the water surface. A clean-out should also be provided. The basin should be placed below the frost line. It should be accessible for cleaning and should be covered with a removable tight cover made of cast iron or masonry.

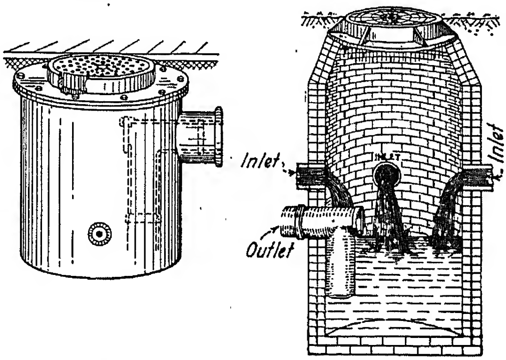


FIG. 164.—Two types of catch basins.

Catch basins are constructed of masonry, concrete, vitrified clay, or cast iron. They may be of any shape conducive to ease in cleaning such as rectangular, oval, or circular. Their size or capacity depends on the amount of detritus to be stored between cleanings and the rate at which water is passed through them. As this depends entirely on local conditions only such general minimum requirements as are given in the Illinois State Model Plumbing Code can be presented as a guide:

Sand traps and catch basins shall be so designed and placed as to be readily accessible for cleaning. They shall be constructed in the same general manner as provided for grease catch basins in Sec. 76, except that they shall be at least 20 in. inside diameter, and where possible, the outlet shall be at least 4 ft. below the surface of the ground. The outlet shall be submerged at least 8 in. and shall not be less than 15 in. above the bottom of the basin.

Where the waste passing through a sand trap or catch basin may contain foul-smelling matter and said sand trap or catch basin is located within a

courtyard, or within 12 ft. of the outside walls of a building, or within a building, or said sand trap or catch basin is connected to a pipe or receptacle containing sewage or is connected to the plumbing system in such a manner that ventilation through the entering soil pipe is not always possible, said sand trap or catch basin shall be vented with a 4 in. vent pipe terminating as provided in Sec. 134. Said vent pipe shall be connected to the highest practicable point in the sand trap or catch basin.

Basins are constructed in sizes from a diameter or depth of 12 in. up to diameters or side dimensions and depths of 6 ft. or more. The smallest size mentioned might be used on a floor drain and the largest would be used on storm-sewer construction rather than on a yard drain.

Difficulties in connection with catch basins lie primarily in their maintenance. They should be cleaned regularly, but they are usually neglected so that after a period of time they no longer serve their purpose. When not properly located mosquitoes and other flying insects will breed in them. Insect breeding can be minimized by a long tortuous inlet and the exclusion of all light from the basin.

293. Grease Traps.—When hot grease and water are poured down a waste pipe the cooling grease will adhere to the sides of the pipe ultimately clogging it. The clogging will be hastened by the tenacity with which hair, vegetable matter, and other material will adhere to the grease and is present in the discharges. This material undergoes offensive decomposition the odors from which may escape into the house or yard and the source be very difficult to locate. It is essential, therefore, that this grease be removed before it enters a drain pipe. Grease traps are not usually necessary on household sinks because of the relatively small amount of grease wasted from them in comparison with the quantity of hot water used. Where a long, horizontal waste pipe runs from the sink, allowing chilling of the grease in the pipe, clogging may result from a failure to use a grease trap. Grease traps should always be used in restaurants, hotels, and institutions, and the traps should be cleaned frequently. An objection to locating a grease trap within a kitchen is the odor and mess sometimes resulting from the cleaning of the trap. For these reasons traps are sometimes located in the basement or outside of the building but protected from the frost. General regulations and minimum requirements for the location and the construction of grease traps as stated in the Illinois State Model Plumbing Code are as follows:

Grease Traps and Catch Basins; Where Required.—In any building where quantities of grease or oily waste are discharged a water-cooled grease trap shall be provided on each fixture through which such wastes are discharged, or a grease catch basin shall be installed to intercept such wastes before they enter the house drain or the house sewer. Where a grease catch basin is used each fixture shall be separately trapped as provided in Sec. 66.

Whenever possible the grease catch basin shall be installed outside of the wall of the building as near as possible to the fixture from which it receives the discharge. Such a trap or catch basin shall be protected, where necessary, against freezing.

No human or fresh animal excrement shall be discharged into a grease trap or grease catch basin.

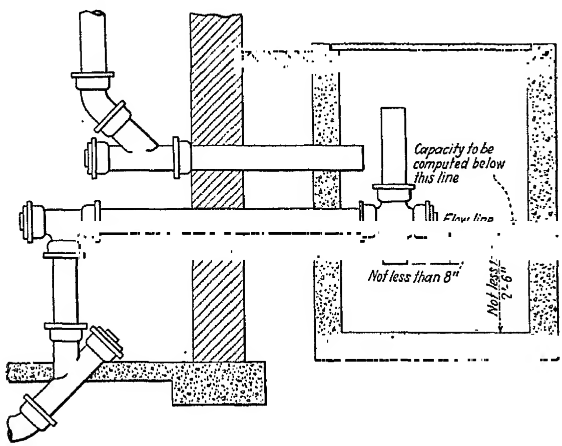


FIG. 165.—Grease catch basin.

Grease Traps.—Where a grease trap is installed it shall be placed as near as possible to the fixture from which it receives the discharge and it shall have double the capacity of said fixture. It shall conform in every respect to the requirements of Secs. 63 and 65, except that it need not be self-cleaning. The outlet leg shall be so vented or installed as to preclude the possibility of self-siphonage.

Grease Catch Basins; Construction.—A grease catch basin shall be constructed in a water-tight and substantial manner of steel, iron, brick, concrete, vitrified clay, or masonry. The outlet pipe shall be one size larger than the inlet pipe and in no case less than 4 in.

The outlet shall be provided with an inverted bend or cleanout, shall be submerged at least 8 in., and shall not be less than 2 ft. 6 in. above the bottom and shall be so vented and installed as to preclude the possibility of self-siphonage. The inlet shall not be submerged. The capacity of the catch basin shall not be less than twice the average hourly inflow. The catch basin should have an air-tight masonry, vitrified clay, or metal cover.

The type of construction recommended is illustrated in Fig. 165. A type of water-cooled grease trap to be installed below a kitchen sink is shown, in sectional view, in Fig. 166. The water chamber surrounding the drain pipe is connected to the water-supply system. The water pipe should then lead to the hot-water storage tank so that the cooling water from the grease trap will flow into the hot-water storage tank.

The size of the grease trap or catch basin is fixed by the rate of flow through it. The capacity of non-cooled grease traps should be at least twice the amount of water which may be discharged into them at one time. The Illinois State Board of Health fixes this as not less than twice the hourly inflow. Water-cooled grease traps may be made smaller because of the greater rapidity with which the grease is cooled

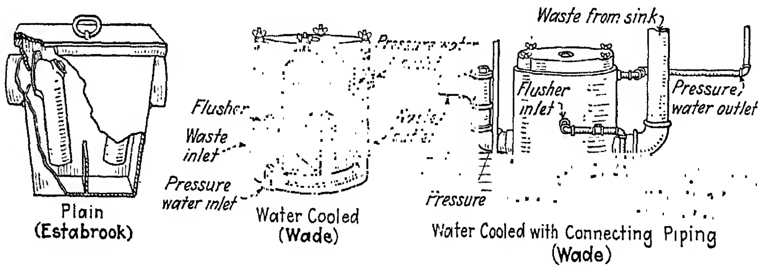


FIG. 166.—Plain and water-cooled grease traps.

Grease traps under a sink should be constructed of iron—either black, painted, or enameled. Traps or catch basins outside of the building may be constructed of any material suitable for an ordinary catch basin but special care should be observed to secure water-tight and air-tight construction, an adequate trap, and convenient clean-out facilities both for the grease trap and the drain pipes. It is essential that the trap be cleaned frequently as otherwise clogging will occur.

294. Gasoline and Oil Traps.—Gasoline and oil traps are constructed on similar principles to grease traps but they are not water cooled. The details of an oil separator are shown in Fig. 167. They should be located on all garage drains, the drains from cleaning establishments, and other places where explosive and inflammable materials may enter a sewer. Minimum requirements for the design, location, and construction of such

traps are given in the Illinois State Model Plumbing Code as follows:

A gasoline and oil trap shall be provided on the waste from all garages, automobile wash floors, cleaning establishments, or establishments from which gasoline, benzene, or other similar substance may be discharged. Said trap shall be installed on the waste pipe above its junction with any other pipe or receptacle containing sewage. The passing of human or fresh animal excrement through such a trap is prohibited.

A gasoline and oil trap shall be constructed in the same general manner as provided for a grease catch basin in Sec. 76. The capacity of the gasoline or oil trap shall be not less than twice the average hourly inflow.

All gasoline and oil traps shall be vented with a 4-in. or larger vent pipe leading from the highest practicable point in the trap and terminating as provided in Sec. 134.

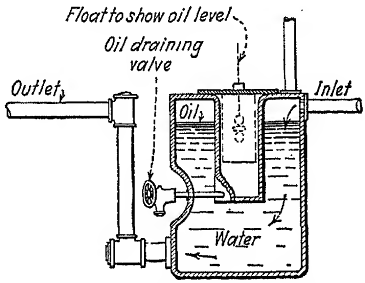


Fig. 167.—Oil separator. (*Plumbers Trade Journal*, Vol. 76, p. 567.)

295. Water Meters.*—It takes energy to supply water to a building or other point of demand for water, and energy costs money. It is true from certain points of view that water is free but it costs money to collect it, purify it, pump it, distribute it, and to support the necessary activities of a waterworks department. This money is supplied either by the tax payers or the consumers or both—usually both, because they are the same persons. Where flat rates are depended on for distributing the expense and meters are not used, the small consumer practically always pays more than his proportionate share of the burden. Every householder should, therefore, insist on the installation of a meter for his own protection except in those unusual municipalities where meter rates are unjustly high. The three principal disadvantages to the use of meters are their first cost, the expense of maintenance which is usually negligible unless the meter is

* See Standard Specifications for Cold Water Meters of the Am. Water Works Assn., Sec. 20, Appendix I.

abused, and the loss of pressure. This loss may be as high as 25 lb. per square inch in small meters for domestic service when discharging at full capacity. Loss of pressure in venturi meters and in meters over 6 in. in diameter is negligible. The emphasis on the preceding presentation of facts concerning the advantages and disadvantages of the use of water meters has been placed on the financial saving to the small consumer. Equal advantages can be shown to acrue to all; the waterworks department, the large consumer, and the small consumer. The fundamental justice of paying for things received in proportion to the amount received is the fundamental of true economy and should appeal to any fair mind.

296. Types of Water Meters.—Water meters are known as either displacement meters or velocity meters. There are a number of different types of displacement meters on the market which are known by the motion of the piston, as, reciprocating, rotary, oscillating, and nutating disc meters. A displacement meter is one which measures the quantity of flow by recording the number of times a container of known volume has been filled and emptied. A velocity meter is one which measures the velocity of flow past a cross-section of known area. The product of the velocity and the area will give the rate of flow at the instant of observation. An integrating device is necessary to record the total flow. Disc and piston meters are examples of displacement meters. Turbine and venturi meters are classed as velocity meters. Displacement meters are suitable only for low flows and velocity meters only for high flows. The capacities and dimensions of various types of meters are shown in Table 147.

Meters with moving parts, which classification includes all turbine and disc meters, are sometimes protected by some form of screen, usually called a fish screen, to prevent the entrance of large objects into the meter. All meters should be self-cleansing to prevent the accumulation of grit and other detritus from clogging the meter and wearing the moving parts. They should be so constructed that in case of freezing some inexpensive and easily replaceable part will break relieving the strain on other parts. Some meters are made partly of glass and fragile cast iron for this purpose.

297. Setting of Meters.—In setting a meter in a residence it should be placed on the house side of a stop-and-waste valve which is close to the wall through which the water-supply pipe

enters the building. The meter should be well supported, and it should be protected against frost, vibration, and blows. It should be connected with unions on each end so that it can be easily disconnected and it should be so installed that all water can be drained from it, and when water is turned into it air will not become pocketed in the meter. Water should be turned into a meter slowly to avoid damaging the meter by water hammer.

298. Capacity and Accuracy.—So far as accuracy and durability go there seems little to influence the choice between any of the meters now put on the market by the half-dozen or more reputable manufacturers. As regards loss of head, however, meters of different makes now on the market show considerable variation. It may easily be that a smaller meter of one make, therefore of

Table 93.—Losses of Pressure through Water Meters

(Feet of water)

Flow in g.p.m.	Meters of various makes. "Hartford Tests," *Eng. News Record*, Dec. 12, 1918	Niagara discount meters all new. Interpolated from tests by V. R. Fleming at University of Illinois				Flow in g.p.m.	3 in. compound meters of various makes. *Jour., American Waterworks Association*, Vol. 8, p. 130
	¾ in.	¾	1	1¼	1½		
5	....	2.0	1.1	0.7	0.2	75	5 to 46
10	5 to 11	8.2	3.2	1.3	0.3	150	7 to 46
15	7 to 25	17.2	6.3	2.4	0.7	225	11 to 48
20	9 to 41	29.8	10.5	3.6	1.7	300	21 to 71
25	14 to 68	46.5	16.0	5.2	2.6	375	30 to 97
30	21 to 92	....	22.7	7.5	4.0	550	44 to 104
35	....	....	29.5	10.2	5.5	525	58 up
40	....	....	39.0	12.9	7.0		
45	....	....	....	16.0	9.0		
50	....	....	....	19.4	10.8		
60	....	....	....	27.2	15.0		
70	....	....	....	37	21.0		
80	....	....	....	....	27		

less cost, will do the work as efficiently as a larger and more costly meter of a different make. In general, within the field of their adaptation meters can be relied upon for accuracies greater than 99 per cent, although errors of 30 and 40 per cent have been found in some meters under unusual circumstances. In selecting

the sizes of meters the practice of the Passaic Water Company of New Jersey is to select the following:

	Size, Inches
Five families or less	5/8
Six to twelve families	3/4
Thirteen to eighteen families	1
Nineteen to thirty families	1½

It usually is better to select undersized than oversized meters because, in oversized meters, although the life may be long, the accuracy will be low and the loss of head will probably be high. The loss of pressure through meters is appreciable and offers an objection to their use. Approximate values of pressure losses in various types of meters are given in Table 93.

299. The Disc Meter.—A sectional view of a disc meter, given in Fig. 168, shows the most common type used for relatively low rates of flow to residences. Water passing through the chamber in which the disc is located causes the disc to oscillate about its central spherical bearing with a spiral motion. The oscillation of the disc measures the filling and emptying of the disc chamber. The oscillations are transferred to the train of gears shown in the upper part of the meter and the number of oscillations of the disc is recorded at the top of the meter in terms of the volume of water which has passed through the meter.

Two types of meter dials are shown in Fig. 169. In the circular register each digit in the number expressing the amount of flow is shown on a different indicator, that is, one indicator shows the digit in the thousands place, another that in the hundreds place, a third that in the tens place, and a fourth the units, or other arrangements of indicators may be used. The "straight reading" dial shows the total flow directly in one place on the dial. Either type is satisfactory, but the former is more simple in construction and is more generally used.

All of the moving parts of the disc meter are of metal except the disc and its spherical bearing which are made of a composition not unlike hard rubber. The material is seriously affected by hot water, and where there is danger of hot water backing through the meter a check valve should be installed as a protection. Meters made entirely of metal are available for measuring hot water.

The accuracy of disc meters is very high even for extremely low rates of flow and they maintain this accuracy through years

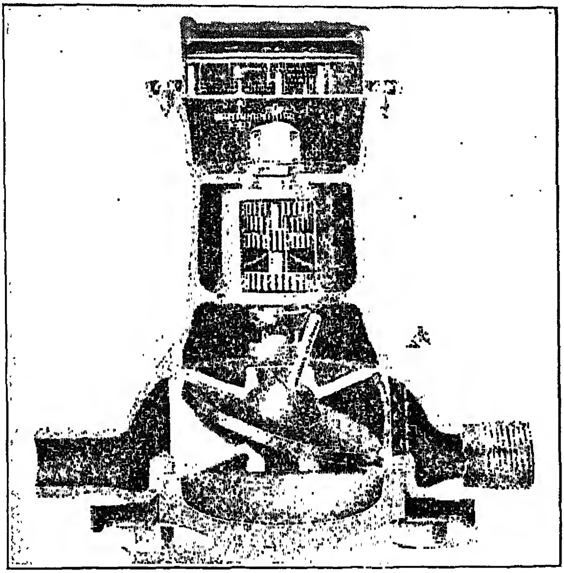
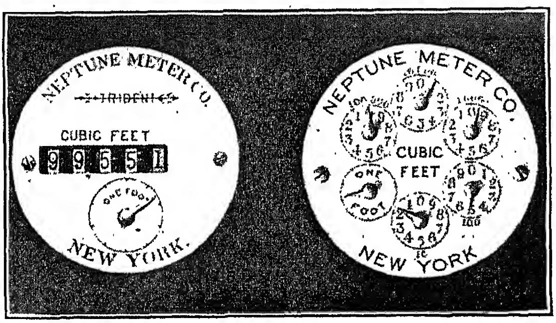


FIG. 168.—Section of a disc meter. (*Neptune Meter Company.*)

of service. When in error they usually register less than the actual flow and almost all accidents of service tend to cause too



Straight reading register Circular reading register

FIG. 169.—Meter indicator dials. (*Neptune Meter Company.*)

low a record. The maximum errors normally found seldom exceed a fraction of 1 per cent.

300. Turbine Meters.—A turbine meter is illustrated in Fig. 170. This is a velocity meter the velocity of the water flowing through the meter being measured by the speed of revolution of the turbine wheel. All of the parts of the meter are of metal and they are suitable for use with hot water and, when properly constructed, for some corrosive liquids. The accuracy of turbine meters, within the limits of their capacities is satisfactory but they have both an upper and a lower limit of usefulness.

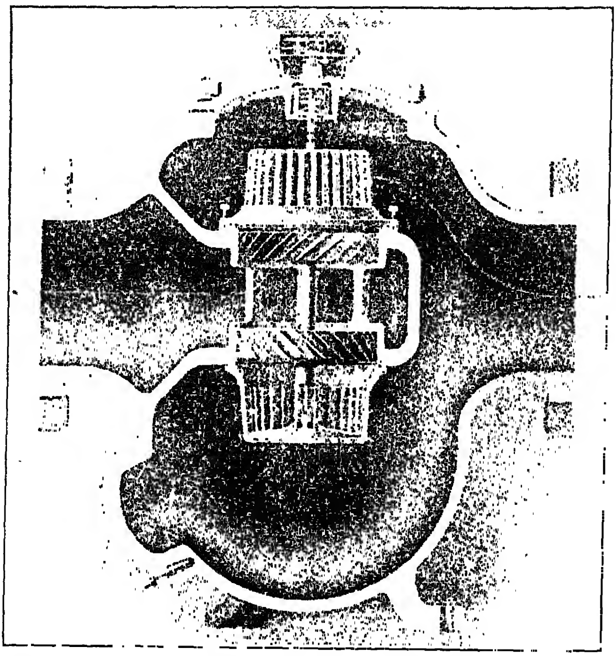


Fig. 170.—Section of a turbine meter. (*Neptune Meter Company.*)

301. Compound Meters.—To overcome the inaccuracies of turbine meters at low flows a compound meter has been designed which combines a disc meter and a turbine meter. The former measures the low flow, the latter the high flow. When one part of the meter is recording the other part is idle. Such meters have been shown by test to give high accuracy for all rates of flow.

The Standard Specifications of the American Waterworks Association describes a compound meter as follows:

A compound meter consists of the combination of a main-line meter of the current or displacement type and a small by-pass meter of the displacement type for measuring small flows, together with an automatic valve mechanism for diverting the small flows through the by-pass meter. Fire-service meters are compound meters . . . designed to afford a clear passage through the meter when the (automatic by-pass) valve is raised from its seat.

302. Venturi Meters.—A venturi meter operates without moving parts and, hence, is the simplest type of meter in use so far as its construction is concerned. It is a velocity meter and it is suitable for measuring only high rates of flow. Rates of flow below its capacity limit are not accurately measured. It is not, therefore, suitable for use in measuring the low intermittent demand by most consumers and its installation by the plumber will seldom be called for. The measurement of flow through a venturi meter is dependent on the fact that when water flows through the constricted portion of a pipe the velocity through the constricted portion, or throat, is greater than the velocity in the approach pipe, and the pressure at the throat is less than the pressure in the approach pipe. The decrease in pressure is directly proportional to the square of the decrease in velocity of flow. Hence, the difference between the pressure in the approach pipe and the pressure at the throat of the constriction is a direct measure of the rate of flow at the moment of observation and this can be indicated on a gage. A somewhat complicated and expensive integrating mechanism is necessary to show the total flow through such a constriction or meter.

303. Refrigerating Machines.—The increasing popularity and widespread use of refrigerating machines should awaken the plumber to the need for knowledge of the principles of their operation as he is most likely to be called upon for repairs or service. The general principle of operation of all refrigerating machines is as follows: a gaseous medium is compressed; the temperature of the gas rises as it is compressed, that is, it gives off heat; the hot gas is passed through cooling coils and the temperature reduced to that of the surrounding medium, usually either cooling water or air; the cooled gas or liquified gas is allowed to expand suddenly through an orifice; the expanding gas becomes cold, that is it absorbs heat; the heat may be absorbed directly through refrigerating coils placed near the expanding gas so that the coils will be chilled, or the heat may be

absorbed from a liquid medium surrounding coils in which the expansion of the gas takes place; the chilled liquid medium is circulated through the refrigerating coils in that portion of the machine in which the cooling of the materials stored in it is to take place; the expanded gas is returned to the compressor to be used over again. No loss of gas is experienced from such a

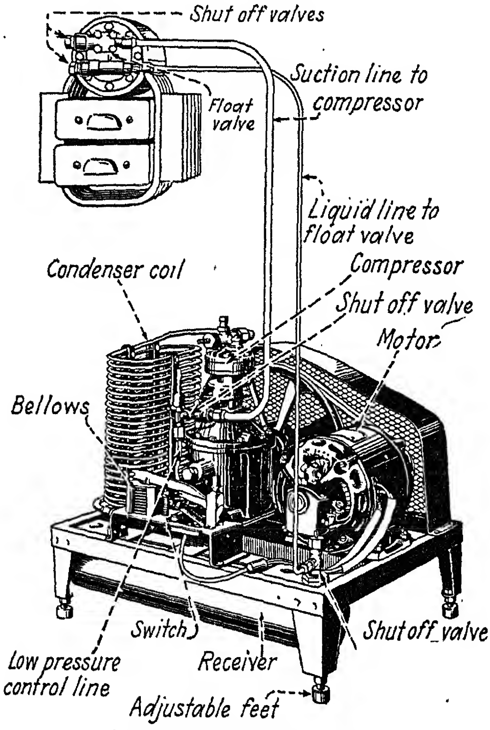


FIG. 171.—Mechanism for a domestic refrigerating machine. (*Frigidaire.*)

system unless there are leaks. The mechanism of a domestic refrigerating machine is shown in Fig. 171.

The gaseous media used in household refrigerating machines are sulphur dioxide, methyl chloride, and ammonia. Large refrigerating machines in cold-storage warehouses and ice factories use ammonia almost exclusively. The liquid to be used around the expansion nozzle and the coils in refrigerating machines is usually a saturated solution of calcium chloride known as brine.

In the operation of a domestic machine, an electric motor is used to drive the compressor. This motor is automatically controlled by a thermostat placed in the refrigerator compartment so that any desired temperature can be constantly maintained. Machines are available which will maintain temperatures below zero Fahrenheit. Domestic machines are set for temperatures of about 50° F. in the food compartment and about 30° F. in the ice-making compartment.

The amount of electric current consumed is, of course, dependent on the size of the ice box, its construction, the frequency with which the box is opened and the time it is left open, and other conditions. In general, however, it is claimed that the maintenance of such machines is less costly than an ice-cooled refrigerator, fixed charges included. The objections to their use lie in their first cost, the danger from leakage of the gas, and in the amount of mechanism to go wrong. The advantages gained from their use seem to outweigh the objections.

304. Drinking Fountains.—The drinking fountain represents one of the latest plumbing fixtures to be introduced. Its adoption accompanied the campaign for the abolition of the common drinking cup. The fundamental purpose of the fountain is, therefore, to supply clean water which has not been contaminated by the previous drinker. Fountains are frequently very beautifully designed and if attractively located will serve as an ornament as well as to supply water. Fountains are made of porcelain, vitreous ware, enameled iron, stoneware, cement, cast or pressed metal, and other materials. Some fountains are equipped with a small trough containing water placed near the ground for the use of small animals.

In the selection of a fountain, of which many types are available and a few of which are shown in Fig. 172, its purpose should be kept in mind, that is, to supply water without permitting the lips of the drinker to touch the fountain and to prevent water from dripping back on to the nozzle. The nozzles shown at *A*, *B*, and *C* in the figure do not fulfill this requirement; the nozzles at *D*, *E*, and *F*, approach the desired conditions, and the nozzles at *G*, and *H* attain it. An objection to the latter type of nozzle or spray is the difficulty sometimes experienced in attempting to drink from it.

The fountain nozzle should be so constructed that a high velocity spray cannot shoot up out of the nozzle. This can be

accomplished by the construction of the outlet orifice larger than the inlet pipe so that the velocity is reduced. Slits cut in the side of the nozzle will discourage mischievously inclined persons from squirting water around. The inlet should be so adjusted, by means of a special valve not easily found by the casual user, that only a gentle stream will issue from the fountain with the

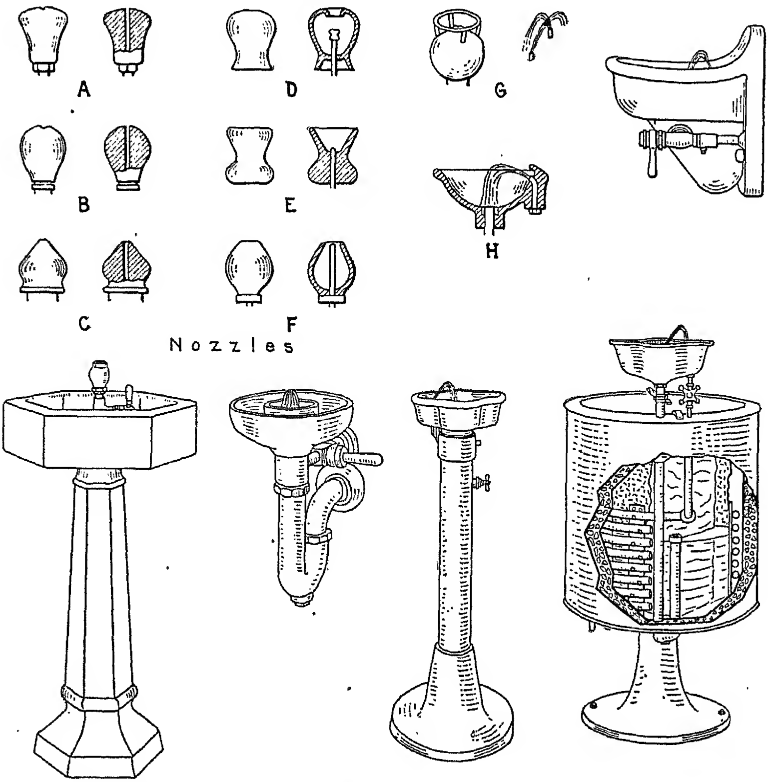


FIG. 172.—Types of bubbling drinking fountains and nozzles.

control valve wide open. The control valve should be in plain view and should be comfortably within the reach of the user, unless the fountain is to run continuously.

The nozzle may be of brass, which is either plain or nickel plated, enameled iron, porcelain, or other material. It should be placed about 36 to 40 in. above the floor or ground. The use of the fixed cup surrounding the nozzle, usually for the purpose

of keeping the lips away from the nozzle, defeats its own purpose because the lips will come into contact with the cup. Cafeteria drinking fountains are supplied with a special type of nozzle, one type of which is shown in Fig. 66. The nozzle and control valve are so arranged that the patron can hold the glass and control the flow of water into it with one hand.

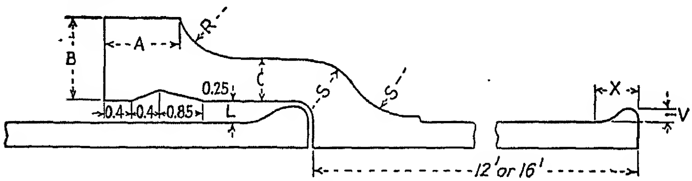
The supply pipe to the bubbling fountain should be $\frac{3}{8}$ in. in diameter and the waste pipe should not be less than $1\frac{1}{4}$ in. in diameter. The waste pipe should be trapped if discharged into any other fixture or pipe containing other wastes. Where floor drains or other infrequently used fixtures exist the fountain waste should be led into their traps.

305. Miscellaneous Fixtures.—The plumbing trade is not confined to the wiping of joints and the cleaning out of stopped-up pipes. As in all other walks of life, it must advance. One form of the advance can include the sale, installation, and servicing of various fixtures using water, steam, or gas and requiring pipe connections. Some fixtures of this type which are of wide use are discussed in preceding sections. Others include: a dental chair with cuspidor, a hospital operating table, sterilizers for various purposes, coffee urns in restaurants, soda fountains, washing machines, clothes dryers, ironers or mangles, etc. Each machine is of special character and information concerning its roughing-in and installation should be obtained from the manufacturer. A feature of many of the installations of such fixtures is the necessity for flexible connections which will permit considerable vibration and movement.

APPENDIX I

EXTRACTS FROM STANDARD SPECIFICATIONS FOR PIPES, FITTINGS, AND MATERIALS USED IN PLUMBING

1. Cast-iron Water Pipe and Fittings with Bell-and-spigot Ends.—From Standard Specifications of the American Waterworks Association, adopted May 12, 1908.



Dimensions

Depth of Bell = 4″
x = ¾″ on sizes from 3″ to 6″ and 1″ on sizes 8″ to 36″
V = 3/16″ on sizes from 3″ to 6″ and ¼″ on sizes 8″ to 36″
A = 1½″ on sizes 4″ to 14″
B = 1.3″ on size of 4″; 1.4″ on size of 6″; 1.5″ on size of 8″ and 10″ for classes A and B, and 1.6″ on size of 10″ for classes C and D and on size of 12″ for Classes A and B.
C = .65″ on size of 4″; .7″ on size of 6″; .75″ on size of 10″ for Classes A and B; .8″ on size of 10″ for Classes C and D and on size of 12″ for Classes A and B; .85″ on size of 12″ for Classes A and B.

FIG. 173.—Section through a bell-and-spigot, cast-iron water pipe.

TABLE 94.—STANDARD DIMENSIONS OF CAST-IRON WATER PIPE

(Adopted by American Waterworks Association, 1908, see Fig. 173)

Bell and spigot

Nominal diameter, inches	Classes	Actual outside diameter, inches	Diameter of sockets		Depth of sockets		Dimensions in inches		
			Pipe, inches	Special castings, inches	Pipe, inches	Special castings, inches	*A*	*B*	*C*
4	*A*	4.80	5.60	5.70	3.50	4.00	1.5	1.30	0.65
4	*B-C-D*	5.00	5.80	5.70	3.50	4.00	1.5	1.30	0.65
6	*A*	6.90	7.70	7.80	3.50	4.00	1.5	1.40	0.70
6	*B-C-D*	7.10	7.90	7.80	3.50	4.00	1.5	1.40	0.70
8	*A-B*	9.05	9.85	10.00	4.00	4.00	1.5	1.50	0.75
8	*C-D*	9.30	10.10	10.00	4.00	4.00	1.5	1.50	0.75
10	*A-B*	11.10	11.90	12.10	4.00	4.00	1.5	1.50	0.75
10	*C-D*	11.40	12.20	12.10	4.00	4.00	1.5	1.60	0.80
12	*A-B*	13.20	14.00	14.20	4.00	4.00	1.5	1.60	0.80
12	*C-D*	13.50	14.30	14.20	4.00	4.00	1.5	1.70	0.85

TABLE 95.—STANDARD WEIGHT AND THICKNESS OF BELL-AND-SPIGOT CAST-IRON WATER PIPE

(Adopted by American Waterworks Association, 1908, see Fig. 173)

Nominal diameter, inches	Class *A* 100-ft. head		Class *B* 200-ft. head		Class *C* 300-ft. head		Class *D* 400-ft. head	
	Thickness, inches	Weight of 12-ft. length, pounds	Thickness, inches	Weight of 12-ft. length, pounds	Thickness, inches	Weight of 12-ft. length, pounds	Thickness, inches	Weight of 12-ft. length, pounds
3	0.39	175	0.42	194	0.45	205	0.48	216
4	0.42	240	0.45	260	0.48	280	0.52	300
6	0.44	370	0.48	400	0.51	430	0.55	460
8	0.46	515	0.51	570	0.56	625	0.60	670
10	0.50	685	0.57	765	0.62	850	0.68	920
12	9.54	870	0.62	985	0.68	1,100	0.75	1,200

Class *E* for 500-ft. head; *F* for 600-ft. head, *G* for 700-ft. head, and *H* for 800-ft. head.

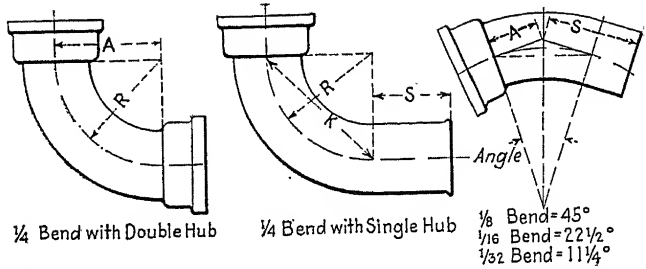


FIG. 174.—Standard specials. Bell-and-spigot, cast-iron water pipes. Bends. (See Table 96)

TABLE 96.—STANDARD WEIGHTS AND DIMENSIONS OF BELL-AND-SPIGOT CAST-IRON BENDS OR CURVES

(Adopted by American Waterworks Association, 1908. Dimensions in inches; weights in pounds, see Fig. 174)

Diameter	One-fourth curve				One-eighth curve			One-sixteenth curve			One-thirty-second curve		
	A	S	Weight 1 bell	Weight 2 bells	R	A	Weight 1 bell	R	A	Weight 1 bell	R	A	Weight 1 bell
4	16	24	82	94	24	9.94	66	48	9.55	66	120	11.82	66
6	16	24	130	140	24	9.94	105	48	9.55	105	120	11.82	104
8	16	26	200	211	24	9.94	150	48	9.55	150	120	11.82	150
10	16	28	278	280	24	9.94	202	48	9.55	202	120	11.82	192
12	16	28	366	366	24	9.94	265	48	9.55	265	120	11.82	250

All are class D. In one-fourth bend $R = A$. $S = A + 6$ in. on one-eighth and one-sixteenth curve. $S = A$ on one-thirty-second curve.

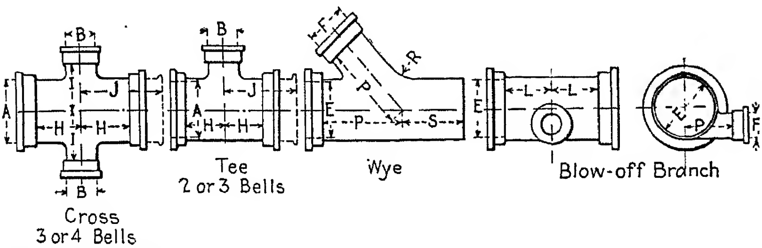


Fig. 175.—Standard specials. Bell-and-spigot, cast-iron water pipe. Tees, crosses, wyes, and blow-off branches.

(See Table 97)

Table 97.—Standard Weights and Dimensions of Bell-and-spigot Cast-iron Tees, Crosses, Wyes, and Blow-off Branches

(Adopted by American Waterworks Association, 1908. Dimensions in inches; weights in pounds, see Fig. 175)

All fittings, diameter		Tees and crosses						Wyes			Blow-off		
				Weight									
				Tees		Crosses							
Run	Branch	*H*	*J*	2 bells	3 bells	3 bells	4 bells	*P*	*S*	Weight	*L*	*P*	Weight
4	3	11	23	121	120	153	153						
4	4	11	23	125	128	164	166	10.5	11.5	103			
6	3	12	24	173	170	207	204						
6	4	12	24	185	183	223	221	12.0	12.0	159			
6	6	12	24	203	200	259	257	13.0	13.0	181			
8	4	13	25	262	255	301	294	14.0	14.0	221	12	7	227
8	6	13	25	278	270	333	325	15.0	14.0	253			
8	8	13	25	301	294	378	372	16.0	14.0	291			
10	4	14	26	356	338	395	377	....	....	...	12	8	286
10	6	14	26	371	352	424	406	17.0	15.5	348	12	8	300
10	8	14	26	389	371	461	443	18.0	15.5	392			
10	10	14	26	414	395	411	493	18.5	15.5	434			
12	4	15	27	473	445	514	486	....	....	...	12	10	365
12	6	15	27	486	458	540	512	19.0	15.5	490	12	10	379
12	8	15	27	502	474	573	545	21.5	15.5	553			
12	10	15	27	519	491	605	577	21.5	15.5	588			
12	12	15	27	540	512	651	623	21.5	15.5	632			

All are class D. $H = I$. For wyes $R = 6$ inches.

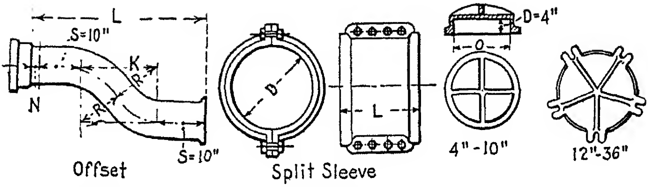


FIG. 176.—Standard specials. Bell-and-spigot, cast-iron water pipe. Offsets, caps, split sleeves.
(See Table 98)

TABLE 98.—WEIGHTS AND DIMENSIONS OF BELL-AND-SPIGOT CAST-IRON OFFSETS, CAPS, AND SPLIT SLEEVES

(Adopted by American Waterworks Association, 1908. Dimensions in inches; weights in pounds, see Fig. 176)

Diameter	Offset				Split sleeves							Caps	
								Bolts		Weight			
	R	*L*	*K*	Weight	*L*	*D*	Diameter of branch	Size	Number	Without branch	With branch	*D*	*O*
4	8	35.85	13.85	91	10	5.70	..	0.75	6	72	...	4.0	5.70
6	14	46.25	24.25	183	10	7.80	4	0.88	6	86	109	4.0	7.80
8	15	48.00	26.00	280	12	10.00	4	1.00	6	133	156	4.0	10.00
10	16	49.70	27.70	390	12	12.10	4	1.13	6	158	181	4.0	12.10
12	17	51.45	29.45	530	14	14.20	6	1.13	8	222	255	4.0	14.20

All are class D.
In offsets $S = 10$ in., and $N = 2$ in., all sizes.

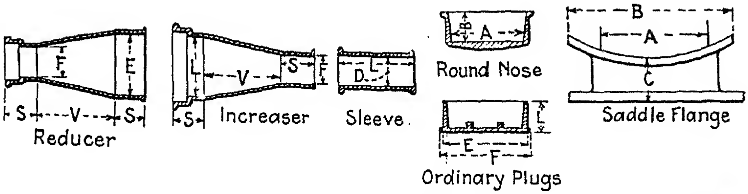


FIG. 177.—Standard specials. Bell-and-spigot, cast-iron water pipe. Plugs, sleeves, reducers.
(See Table 99)

TABLE 99.—STANDARD WEIGHTS AND DIMENSIONS OF BELL-AND-SPIGOT CAST-IRON PLUGS, SLEEVES, AND REDUCERS

(Adopted by American Waterworks Association, 1908. Dimensions in inches; weights in pounds, see Fig. 177)

Reducers					Sleeves				Plugs					
			Weights											
E	*F*	Spigot ends	Large end bell	Small end bell	Diameter	*D*	*L*	Weight	Diameter	*E*	*F*	*L*	Number of ribs	Weight
6	4	82	104	97	4	5.80	10	47	4	4.90	5.28	5.50	..	8
8	4	104	132	119	4	5.80	15	61						
8	6	121	150	143	6	7.90	10	68	6	7.00	7.38	5.50	..	14
10	4	131	162	146	6	7.90	15	87						
10	6	150	180	169	8	10.10	12	104	8	9.15	9.65	5.50	2	24
10	8	170	201	198	8	10.10	18	119						
12	4	163	201	179	10	12.20	14	123	10	11.20	11.70	6.00	2	38
12	6	181	218	202	10	12.20	18	176						
12	8	202	240	231	12	14.30	15	174	12	13.30	13.80	6.00	2	50
12	10	229	267	261	12	14.30	18	223						

V = 18 in. All are class D.

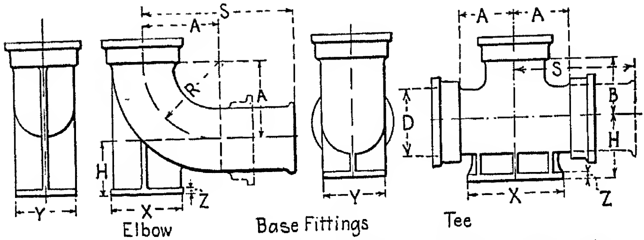


FIG. 178.—Standard specials. Bell-and-spigot, cast-iron water pipe. Base, elbows and tees.
(See Table 100)

TABLE 100.—STANDARD WEIGHTS AND DIMENSIONS OF BELL-AND-SPIGOT CAST-IRON BASE, ELBOWS AND TEES

(Adopted by American Waterworks Association, 1908. Dimensions in inches; weights in pounds, see Fig. 178)

Diameter	90° elbow, bell and spigot or two bells						Tees, three bells or two bells and one spigot							
	S	H	X	Y	Z	Weight one bell	$A = R$	S	H	X	Y	Z	Weight, Two bells	Weight, Three bells
4	24	5.50	9.0	5.0	0.78	107	11	23	5.5	9.0	5.0	0.68	136	139
6	24	6.50	11.0	7.5	0.83	171	12	24	6.5	11.0	7.5	0.72	223	220
8	26	7.50	13.5	9.5	0.90	260	13	25	7.5	13.5	9.5	0.77	333	326
10	28	9.00	16.0	11.5	1.02	366	14	26	9.0	16.0	11.5	0.86	464	445
12	28	10.00	19.0	13.5	1.13	498	15	27	10.0	19.0	13.5	0.93	613	585

For elbows $A = R = 16$ in. All are class D.

2. Cast-iron Water Pipe and Fittings with Flanged Ends.—Adapted from the Standard Specifications of the American Waterworks Association, adopted May 12, 1908.

TABLE 101.—WEIGHTS AND DIMENSIONS OF CAST-IRON WATER PIPE, FLANGED

(For waterworks. Dimensions in inches; weights in pounds, see Fig. 179)

						Class A		Class B		Class C		Class D	
Pipe diameter	Flange diameter	Flange thickness	Bolt circle diameter	Number of bolts	Diameter of bolts	Thickness	Weight per length, 12 ft.	Thickness	Weight per length, 12 ft.	Thickness	Weight per length, 12 ft.	Thickness	Weight per length, 12 ft.
3	7.5	3/4	6.0	4	5/8	0.39	168	0.42	188	0.45	199	0.48	211
4	9.0	15/16	7.5	8	5/8	0.42	234	0.45	259	0.48	275	0.52	295
6	11.0	1	9.5	8	3/4	0.44	358	0.48	398	0.51	421	0.55	451
8	13.5	1 1/8	11.75	8	3/4	0.46	498	0.51	549	0.56	614	0.60	654
10	16.0	1 3/16	14.25	12	7/8	0.50	672	0.57	759	0.62	840	0.68	916
12	19.0	1 1/4	17.0	12	7/8	0.54	876	0.62	998	0.68	1,109	0.75	1,216

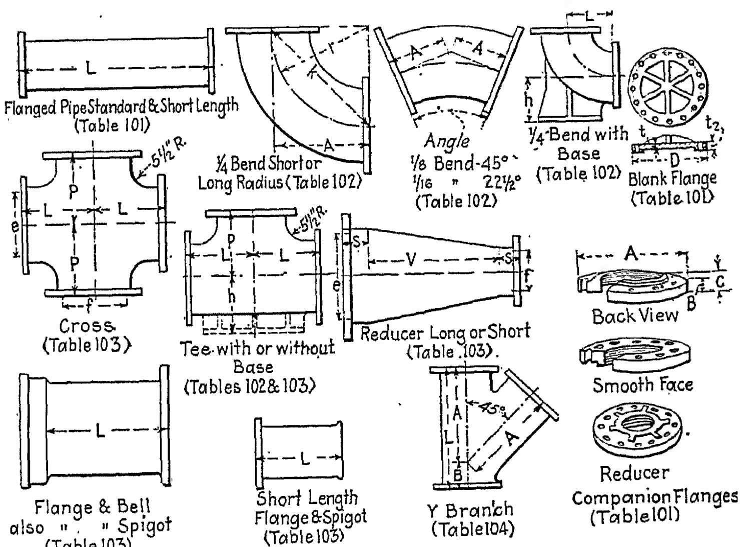


FIG. 179.—Standard specials with flanged ends for cast-iron water pipe.

These are not general standards but are selected from the American and the United States Cast-iron Pipe Companies' Catalogs.

(See Tables 101, 102, 103, 104)

TABLE 102.—WEIGHTS AND DIMENSIONS, CAST-IRON BASE TEES, AND PLAIN AND BASE BENDS, FLANGED

(For waterworks. Dimensions in inches; weights in pounds, see Fig. 179)

Diameter	Weight of			90 deg. plain and base bends		Base tees		
	¼ bend	⅛ bend	1/16 bend	h[1]	Weight	$P = L$	h[1]	Weight
4	69	57	57	5.5	107	11	5.5	139
6	101	83	83	6.5	171	12	6.5	220
8	147	121	121	7.5	260	13	7.5	326
10	209	170	170	9.0	366	14	9.0	445
12	287	238	238	10.0	498	15	10.0	585

For one-fourth bends and base elbows $R = A = 16$ in. For one-eighth bend $R = 24$ in. $A = 9.94$ in. For one-sixteenth bend $R = 48$ in., $A = 9.55$ in.

[1] These are the same for straight or reducing fittings. Dimension on run controls.

TABLE 103.—DIMENSIONS AND APPROXIMATE WEIGHTS OF CAST-IRON TEES, CROSSES, REDUCERS, BLANK FLANGES AND SHORT LENGTHS, FLANGED; AND SHORT LENGTHS, FLANGED AND BELL. FOR WATERWORKS
(Dimensions in inches; weights in pounds, see Fig. 179)

Tees and crosses					Reducers	
			Weight		Weight	
e	f	$L=P$	Tee	Cross	$V = 12$, $S = 2$	$V = 18$, $S = 4$
4	4	11.0	88	114	...	...
6	4	12.0	124	150	67	88
6	6	12.0	137	176	...	...
8	4	13.0	179	191	79	111
8	6	13.0	191	232	91	124
8	8	13.0	209	268	...	...
10	4	14.0	251	277	103	142
10	6	14.0	269	303	115	160
10	8	14.0	280	335	132	183
10	10	14.0	300	392	...	...
12	4	15.0	351	377	123	183
12	6	15.0	364	403	147	200
12	8	15.0	380	435	163	223
12	10	15.0	397	492	187	256
12	12	15.0	426	557		

Short lengths, weights Class D										
Length for all	Diameter = 4 in.		Diameter = 6 in.		Diameter = 8 in.		Diameter = 10 in.		Diameter = 12 in.	
	Flange and Spigot	Bell and Flange	Flange and Spigot	Bell and Flange	Flange and Spigot	Bell and Flange	Flange and Spigot	Bell and Flange	Flange and Spigot	Bell and Flange
6	29	45	...	63	...	97	...	131	...	178
12	33	56	48	81	71	123	101	166	139	224
18	45	68	66	99	97	149	137	202	186	271
24	56	79	83	116	123	174	172	238	233	318
30	67	90	101	134	148	200	208	274	280	365
36	79	102	118	151	174	225	244	309	326	412
48	102	125	154	187	225	277	315	381	420	505
60	124	147	189	222	276	328	387	452	514	599
72	147	170	224	257	327	379	458	523	606	691

Blank flanges									
Diameter	D	t	t_2	Weight	Diameter	D	t	t_2	Weight
3	7.5	0.65	0.85	9	8	13.5	0.75	1.03	36
4	9.0	0.65	0.91	14	10	16.0	0.80	1.15	55
6	11.0	0.70	0.96	23	12	19.0	0.85	1.26	84

TABLE 104.—WEIGHTS AND DIMENSIONS OF FLANGED WYES
(Dimensions in inches; weights in pounds, see Fig. 179

Cast-iron water pipe, for waterworks

	American C. I. Pipe Co.				United States C. I. Pipe Co.				
Diameter.....	6	8	10	12	4	6	8	10	12
A...........	21.5	24.0	27.0	30.5	13.5	17.5	20.0	23.0	26.5
B...........	8.0	9.0	9.5	10.0	3.0	4.0	5.0	5.5	6.0
Weight.......	219	354	530	781	97	188			

3. Cast-iron Fittings with Flanged Ends for Water, Steam, and Close Work. American Standard, 1914.

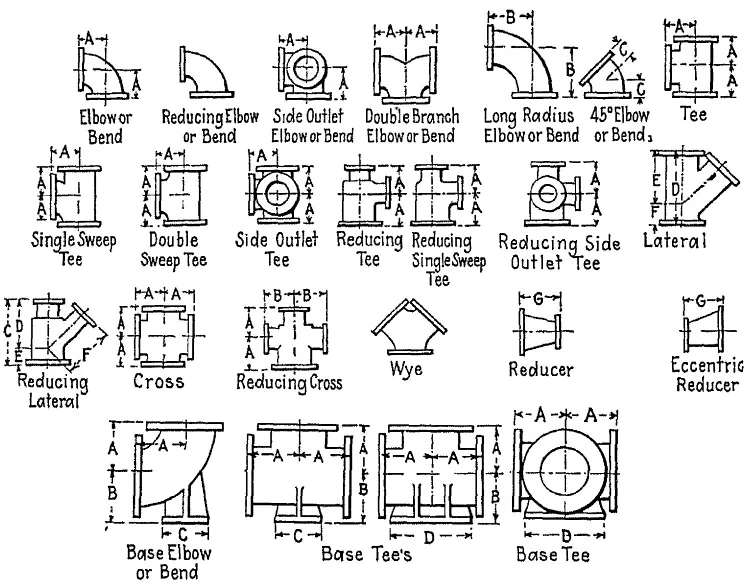


FIG. 180.—American Standard fittings, flanged, for cast-iron pipe.

(For sketches, see Fig. 180)

Low-pressure[1] flanged fittings for close work

Size	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10	12
AA	7	7½	8	9	10	11	12	13	14	15	16	17	18	20	22	24
A[2]	3½	3¾	4	4½	5	5½	6	6½	7	7½	8	8½	9	10	11	12
B	5	5½	6	6½	7	7¾	8½	9	9½	10¼	11½	12¾	14	15¼	16½	19
C[2]	1¾	2	2¼	2½	3	3	3½	4	4	4½	5	5½	5½	6	6½	7½
D	7½	8	9	10½	12	13	14½	15	5½	17	18	20½	22	24	25½	30
E	5¾	6¼	7	8	9½	10	11½	12	2½	13½	14½	16½	17½	19½	20½	24½
F	1¾	1¾	2	2½	2½	3	3	3	3	3½	3½	4	4½	4½	5	5½
G	.....	.....	.....	.....	.....	6	6½	7	7½	8	9	10	11	11½	12	14
Diameter of flanges	4	4½	5	6	7	7½	8½	9	9¼	10	11	12½	13½	15	16	19
Thickness of flanges	7/16	½	9/16	⅝	11/16	¾	13/16	15/16	15/16	15/16	1	1 1/16	1⅛	1⅛	1 3/16	1¼
Diameter of bolt hole circle in flanges	3	3⅜	3⅞	4¾	5½	6	7	7½	7¾	8½	9½	10¾	11¾	13¼	14¼	17
Number of bolts	4	4	4	4	4	4	4	8	8	8	8	8	8	12	12	12
Size of bolts[4]	7/16	7/16	½	⅝	⅝	⅝	⅝	⅝	¾	¾	¾	¾	¾	¾	⅞	⅞
Length of bolts	1½	1½	1¾	2	2¼	2¼	2½	2¾	2¾	2¾	3	3	3¼	3¼	3½	3½

Extra heavy[5] flanged fittings

Size	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10	12
AA[9]	8	8½	9	10	11	12	13	14	15	16	17	18	20	21	23	26
A[2]	4	4¼	4½	5	5½	6	6½	7	7½	8	8½	9	10	10½	11½	13
B	5	5½	6	6½	7	7¾	8½	9	9½	10¼	11½	12¾	14	15¼	16½	19
C[2]	2	2½	2¾	3	3½	3½	4	4½	4½	5	5½	6	6	6½	7	8
D	8½	9½	11	11½	13	14	15½	16½	18	18½	21½	23½	25½	27½	29½	33½
E	6½	7¼	8½	9	10½	11	12½	13½	14½	15	17½	19	20½	22½	24	27½
F	2	2¼	2½	2½	2½	3	3	3	3½	3½	4	4½	5	5	5½	6
G	.....	.....	.....	.....	.....	6	6½	7	7½	8	9	10	11	11½	12	14
Diameter of flanges	4½	5	6	6½	7½	8¼	9	10	10½	11	12½	14	15	16¼	17½	20½
Thickness of flanges	1 1/16	¾	1 3/16	⅞	1	1⅛	1 3/16	1¼	1 5/16	1⅜	1 7/16	1½	1⅝	1¾	1⅞	2
Diameter of bolt hole circle in flanges	3¼	3¾	4½	5	5⅞	6⅝	7¼	7⅞	8½	9¼	10⅝	11⅞	13	14	15¼	17¾
Number of bolts	4	4	4	4	4	3	8	8	8	8	12	12	12	12	16	16
Size of bolts[4]	½	½	⅝	⅝	¾	¾	¾	¾	¾	¾	¾	⅞	⅞	1	1	1⅛
Length of bolts	2	2¼	2½	2½	3	3¼	3¼	3½	3½	3¾	3¾	4	4¼	4¾	5	5¼

For footnotes see page 364.

TABLE 105.—STANDARD DIMENSIONS IN INCHES FOR FLANGED FITTINGS "AMERICAN STANDARD"[10].—(*Continued*)
(For sketches, see Fig. 180)
Base and anchorage fittings

	Size in inches															
	4		4½		5		6		7		8		9		10		12	
S = Standard low pressure *H* = Extra heavy	*S*	*H*	*S*	*H*	*S*	*H*	*S*	*H*	*S*	*H*	*S*	*H*	*S*	*H*	*S*	*H*	*S*	*H*
A, center to face ells and tees	6½	7	7	7½	7½	8	8	8½	8½	9	9	10	10	10½	11	11½	12	13
B, center to face base flanges	6½	7	6¾	7¼	7	7½	7½	8	8¼	8¾	8¾	9¼	9½	10	10	10½	10½	11
C, base flange, across flats of square or diameter of round	6	6½	6	6½	7	7½	7	7½	7	7½	9	10	9	10	9	10	11	12½
D, anchorage flange, across flats of square	9	10	9¼	10½	10	11	11	12½	12½	14	13½	15	15	16	16	17	19	19
Size of pipe support for round-base flange	2	2	2	2	2½	2½	2½	2½	2½	2½	4	4	4	4	4	4	6	6

[1] Low-pressure fittings for steam working pressures up to 25 lb. per square inch, and water working pressures up to 50 lb. per square inch.
[2] Special angle fittings 1 to 45 deg. use center-to-face dimensions of 45 deg. elbow, and 46 deg. to 90 deg. use center-to-face dimensions of 90-deg. elbow.
[3] All reducing fittings have the same center-to-face dimensions as straight size fittings. The dimensions given in the tables are for "short-body" patterns. "Long-body" patterns are used when the outlets are larger than those given in the table, and they have, therefore, the same dimension as straight size fitting.
[4] Bolt holes are drilled ⅛ in. larger than nominal diameter of bolts.
[5] For steam working pressures up to 250 lb. per square inch.
[6] The "long-body" pattern will always be used for fittings reducing on the run only, except double sweep tees, on which the reduced end is always longer than the regular fittings. Dimensions on request to manufacturer.
[7] Bull heads or tees having outlets larger than the run will be the same length center-to-face and face-to-face as a tee with all openings the size of the outlet.
[8] Double branch elbows, whether straight or ordinary, carry same center-to-face dimensions as regular elbows of largest straight size.
[9] All extra heavy flanges have a $\frac{1}{16}$ in. raised face inside of bolt holes. This raised face is included in face-to-face, center-to-face, and thickness-of-flanged dimensions.
[10] For American Standards see Transactions American Society Mechanical Engineers, 1914.
[11] The dimensions of reducing fittings are regulated by the reduction of the outlet or branch.
[12] Reducing elbows carry the same dimensions center-to-face as regular elbows of largest straight size.
[13] All standard weight fittings and flanges have plain faces.
[14] Bolt holes straddle the center line.
[15] Bolt holes will not be spot faced unless so ordered.
[16] Square head bolts with hexagonal nuts are recommended.
[17] Hexagonal nuts on sizes 8-in. and smaller can be conveniently pulled up with open end wrenches of minimum design heads.
[18] Where long radius fittings are specified it has reference only to elbows which are made in two center-to-face dimensions known as elbows and long-radius elbows, the latter being used only when so specified.
[19] Side outlet elbows and side outlet tees, whether straight or reducing, carry the same dimensions, center-to-face and face-to-face as regular tees having the same reductions.
[20] Double-sweep tees are not made reducing on the run.
[21] Standard tees, crosses, and laterals, reducing on run only, carry same dimensions face-to-face as largest straight size.
[22] Tees, crosses, and laterals reducing on the outlet or branch use the same dimensions as straight sizes of the larger port.
[23] Wyes are special and are made to suit conditions.

4. Threaded Cast-iron Fittings for Water Pipe. Manufacturer's Standard.

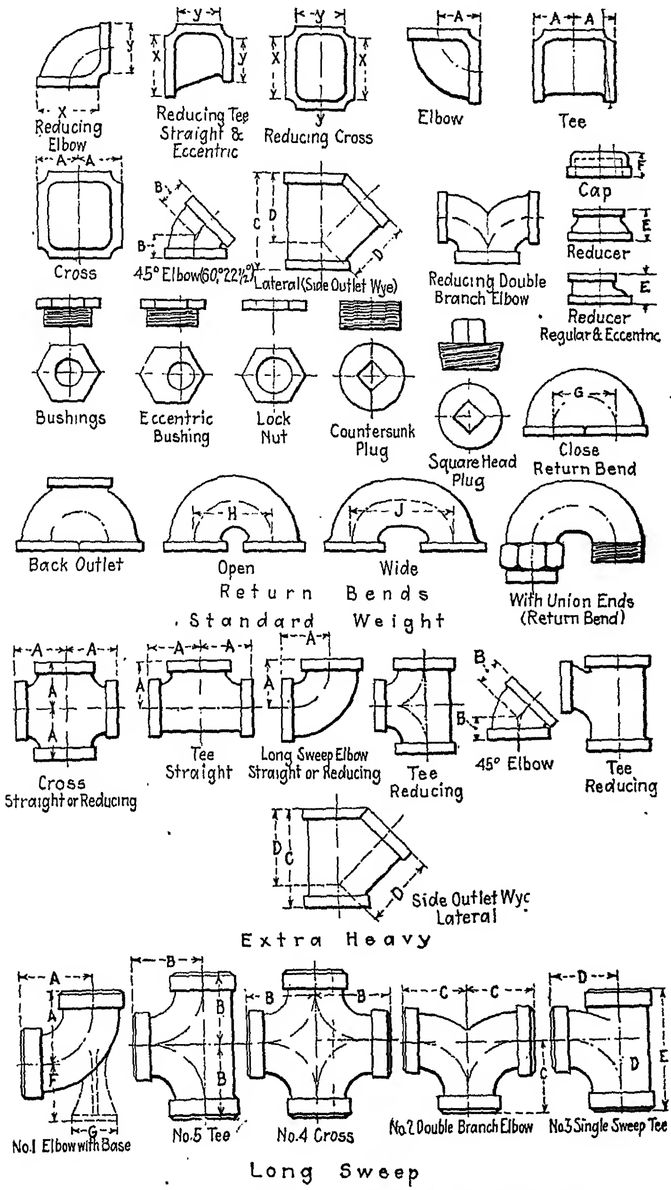


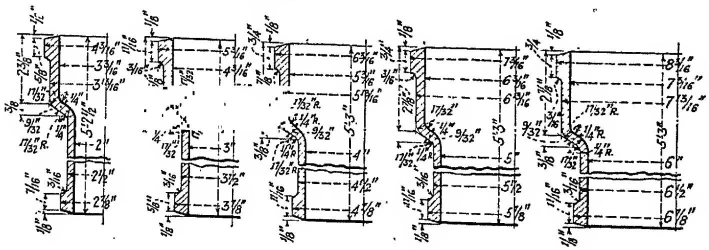
FIG. 181.—Threaded cast-iron fittings for water pipe.
(See Table 106)

TABLE 106.—DIMENSIONS, IN INCHES, OF CAST-IRON THREADED FITTINGS FOR WATER SUPPLY
(Manufacturer's Standard, Crane Co., see Fig. 181)

Size	¼	⅜	½	¾	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10	12
Standard weight																				
A	1 3/16	1 5/16	1⅛	1 5/16	1 7/16	1¾	1 15/16	2¼	2 11/16	3⅛	3 7/16	3¾	4 1/16	4 7/16	5⅛	5 13/16	6½	7 3/16	7⅞	9¼
B	¾	1 3/16	⅞	1	1⅛	1 5/16	1 7/16	1 11/16	1 15/16	2 3/16	2⅜	2⅝	2 13/16	3 1/16	3 7/16	3⅞	4¼	4 11/16	5 3/16	6
C	.....	.....	2½	3	3½	4¼	4⅞	5¾	6¾	7⅞	8⅞	9¾	10⅝	11⅝	13 7/16	15¼	16 15/16	20 11/16	20 11/16	24⅛
D	.....	.....	1⅞	2¼	2¾	3¼	3 13/16	4½	5 3/16	6⅛	6⅞	7⅝	8½	9¼	10¾	12¼	13⅝	16¾	16¾	19⅝
E	.....	.....	.....	.....	.....	2⅛	2¼	2 7/16	2 11/16	2 15/16	3⅛	3⅜	3⅝	3⅞	4⅜	4 13/16	5¼	5 11/16	6 3/16	7⅛
F	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2 1/16	2 3/16	2⅜	2⅝	2⅞	3⅛	3⅜	3⅝	4¼
G	.....	.....	1¼	1½	1¾	2¼	2½	3¼	3¾	4¼										
H	.....	.....	.....	1⅞	2⅜	3	3½	4½	5½	6½										
J	.....	.....	.....	.....	[2]	[3]	[4]	[5]												
Extra heavy																				
A	.....	.....	.....	.....	2	2¼	2 9/16	3	3½	4⅛	4 11/16	5⅛	5½	6⅛	7¼	8⅛	9⅛	.....	11⅜	13⅜
B	.....	.....	.....	.....	1⅜	1½	1⅝	1 15/16	2¼	2½	2 9/16	2¾	3	3 5/16	3¾	4	4¼	.....	4⅞	5½
C	.....	.....	.....	.....	.....	4⅞	5¾	6¾	7⅞	8⅞	.....	10⅝	.....	.....	15¼	16 15/16	18⅛			
D	.....	.....	.....	.....	.....	3 13/16	4½	5 3/16	6⅛	6⅞	.....	8½	.....	.....	12¼	13⅝	14			
Long-sweep fittings																				
A	.....	.....	.....	2	2½	3	3½	4	4½	5	5¾	6½	7¾	7½	9	10½	11¾	13	14½	17
B	.....	.....	.....	2	2½	3	3½	4	4½	5	5¾	6½	7¾	7½	9	10½	11¾	Bush 10	14½	17
C	.....	.....	.....	.....	2½	3	3½	4	5¼	6	6⅝	6½	7¾	9¼	10⅝	10½	11¾	Bush 10	14½	17
D	.....	.....	.....	2	2½	3	3½	4	4¾	5½	5 13/16	7	7¾	8½	9¼	10½	11¾	10	14½	17
E	.....	.....	.....	3	3⅞	4½	5¼	6⅛	7	8⅛	8 13/16	10½	11⅜	12¼	14¼	15½	17⅜	16½	21⅛	24¾
F	.....	.....	.....	.....	.....	.....	.....	.....	5½	5¾	6¼	6½	.....	7	7½					
G	.....	.....	.....	.....	.....	.....	.....	.....	4½	5	5	6	.....	7	7					

Dimensions of reducing fittings not shown.
[2] 3, 4, 5, 6, and 8 in.
[3] 4 and 6 in.
[4] 4⅞, 6, and 8 in.
[5] 4⅞, 6, 7, and 8 in.

5. Cast-iron Soil Pipe and Fittings with Bell-and-spigot Ends.—All cast-iron soil pipe and fittings, other than threaded fittings, should be covered with asphaltum or coal-tar pitch.



Length of Telescoping $2\frac{1}{2}$" Inches for 2 Inch Diameter; $2\frac{3}{4}$" Inches for 3" Diameter; 3 Inches for 4, 5 and 6 Inch Diameters

FIG. 182.—Section through extra-heavy, cast-iron soil pipes with bell-and-spigot ends, showing dimensions.

TABLE 107.—WEIGHTS OF BELL-AND-SPIGOT CAST-IRON SOIL PIPE PER FIVE-FOOT LENGTH, POUNDS

(Weights in pounds, see Fig. 182)

Size, inches	2	3	4	5	6	7	8	10	12
Standard	17½	22½	32½	42	52	75	85	115	165
Medium	20	30	45	60	75	100	125	175	
Extra heavy	27½	47½	65	85	100	135	170	225	270

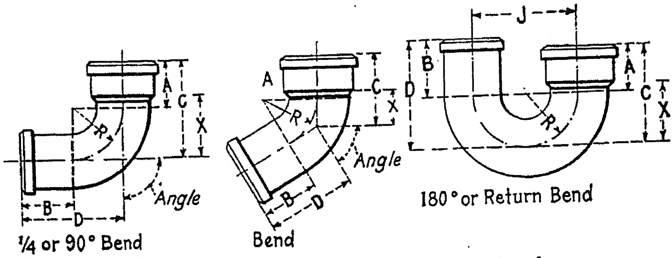


FIG. 183a.—Details of cast-iron soil pipe bends. Dimensions in Table 108.

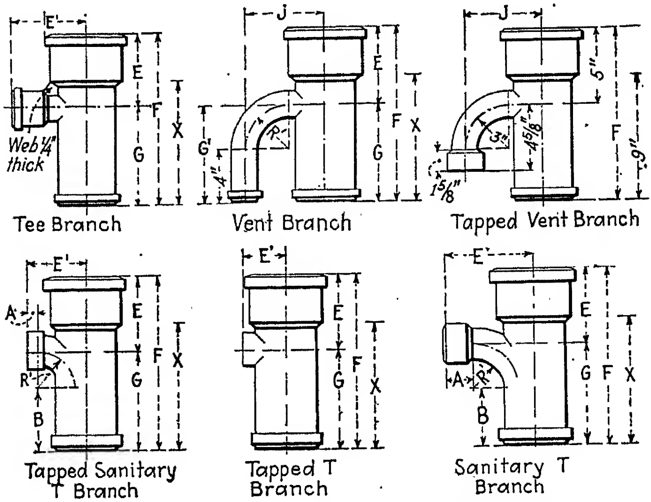


FIG. 183b.—Details of cast-iron soil pipe T branches. Dimensions in Table 109.

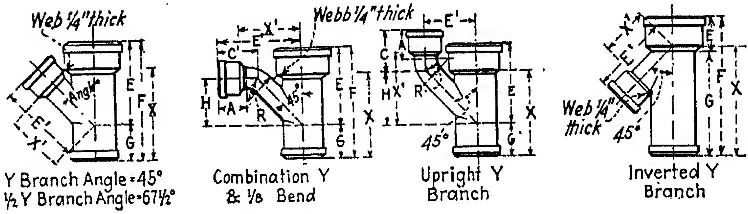


FIG. 183c.—Details of cast-iron soil pipe Y branch. Dimensions in Table 110.

TABLE 108.—WEIGHTS AND DIMENSIONS OF EXTRA HEAVY CAST-IRON SOIL PIPE BENDS. BELL AND SPIGOT

(Manufacturer's standard)

(Dimensions in inches; weights in pounds, see Fig. 183a)

Fitting	Dimension	Size of fitting 2 in.	3 in.	4 in.	5 in.	6 in.
All fittings (except traps and offsets)	A	3	3¼	3½	3½	3½
	B	3	3½	4	4	4
	Regular R	3	3½	4	4½	5
	Short sweep R	5	5½	6	6½	7
	Long sweep R	8	8½	9	9½	10
All traps,[1] offsets[2] regular and one-eighth bends	R	2	2½	3	3½	4
	R	2	2½	3	3½	4
Return or one-half bend, 180 deg.	C	6	6¾	7½	8	8½
	D	6	7	8	8½	9
	X	3¼	4	4½	5	5½
	Wt	8¾	14	20¼	26½	33½
	J	6	7	8	9	10
One-fourth bend, regular 90 deg.	C	6	6¾	7½	8	8½
	D	6	7	8	8½	9
	X	3½	4	4½	5	5½
	Wt	6¾	10¼	15	19	23½
One-fourth bend, short sweep 90 deg.	C	8	8¾	9½	10	10½
	D	8	9	10	10½	11
	X	5½	6	6½	7	7½
	Wt	8¼	12½	17¾	22½	27½

Fitting	Dimension	Size of fitting 2 in.	3 in.	4 in.	5 in.	6 in.
One-fourth bend, long sweep, 90 deg.	C	11	11¾	12½	13	13½
	D	11	12	13	13½	14
	X	8½	9	9½	10	10½
	Wt	10¼	15¾	22	27½	33½
One-fifth bend, 72 deg.	C	5³⁄₁₆	5¹³⁄₁₆	6⁷⁄₁₆	6¾	7⅛
	D	5³⁄₁₆	6¹⁄₁₆	6¹⁵⁄₁₆	7¼	7⅝
	X	2¹¹⁄₁₆	3¹⁄₁₆	3⁷⁄₁₆	3¾	4⅜
	Wt	6¼	9¾	13¾	17½	21½
One-sixth bend, 60 deg.	C	4¾	5¼	5¹³⁄₁₆	6⅛	6⅜
	D	4¾	5½	6⁵⁄₁₆	6⅝	6⅞
	X	2¼	2½	2¹³⁄₁₆	3⅛	3⅜
	Wt	6	9¼	13	16½	20
One-eighth bend, 45 deg.	C	4¼	4¹⁵⁄₁₆	5³⁄₁₆	5⅜	5⁹⁄₁₆
	D	4¼	4¹⁵⁄₁₆	5¹¹⁄₁₆	5⅞	6¹⁄₁₆
	X	1¾	1¹⁵⁄₁₆	2³⁄₁₆	2⅜	2⁹⁄₁₆
	Wt	5½	8½	12¼	15¼	18¼
One-sixteenth bend, 22½ deg.	C	3⅝	3¹⁵⁄₁₆	4⁵⁄₁₆	4⅜	4½
	D	3⅝	4³⁄₁₆	4¹³⁄₁₆	4⅞	5
	X	1⅛	1³⁄₁₆	1⁵⁄₁₆	1⅜	1½
	Wt	5	7¾	10¾	13¼	15¾

[1] The seal to be not less than 2½ in.

[2] The angle of the bends of regular offsets shall not be more than 76 deg. The angle of the bends of one-eighth bend offsets shall be 45 deg. Wye-eighth bend offsets are produced by combining a regular full wye with a regular one-eighth bend, less the hub of the branch of the former and less the spigot end of the latter.

TABLE 109.—WEIGHTS AND DIMENSIONS OF EXTRA HEAVY CAST-IRON SOIL PIPE FITTINGS. TEES BRANCHES. BELL AND SPIGOT

(Dimensions in inches; weights in pounds, see Fig. 183*b*)

(Weights are A. S. T. M. A 74–18 standards. Dimensions are manufacturer's standards)

Size	A	E	E′	F	G	R′	X	Wt	E	E′	F	G	X	Wt
		Tapped sanitary tee branch							Tapped tee branch					
2 by 2	1½	4½	3	11½	7	2½	9	9	4½	2	11½	7	9	8¾
3 by 2	1½	4¾	3½	11¾	7	2½	9	12	4¾	2½	11¾	7	9	11¾
4 by 2	1½	5	4	12	7	2½	9	15¼	5	3	12	7	9	15
5 by 2	1½	5	4½	12	7	2½	9	18	5	3½	12	7	9	17¾
6 by 2	1½	5	5	12	7	2½	9	21¼	5	4	12	7	9	20½
		Sanitary tee branch							Tee branch					
2	3	4½	6	11½	7	3	9	11	4½	4½	11½	7	9	10¼
3	3¼	5¼	6¾	12¾	7½	3½	10	16¼	5¼	5¼	12¾	7½	10	15¼
4	3½	6	7½	14	8	4	11	22½	6	6	14	8	11	21
5	3½	6½	8	15	8½	4½	12	28	6½	6½	15	8½	12	26½
6	3½	7	8½	16	9	5	13	34½	7	7	16	9	13	32½
3 by 2	3	4¾	6½	11¾	7	3	9	14	4¾	5	11¾	7	9	13¼
4 by 2	3	5	7	12	7	3	9	17¼	5	5	12	7	9	16½
4 by 3	3¼	5½	7¼	13	7½	3½	10	19¾	5½	5¾	13	7½	10	18¾
5 by 2	3	5	7½	12	7	3	9	20	5	6	12	7	9	19¼
5 by 3	3¼	5½	7¾	13	7½	3½	10	23	5½	6¼	13	7½	10	22
5 by 4	3½	6	8	14	8	4	11	25½	6	6½	14	8	11	24½
6 by 2	3	5	8	12	7	3	9	23	5	6½	12	7	9	22½
6 by 3	3¼	5½	8¼	13	7½	3½	10	26	5½	6¾	13	7½	10	25
6 by 4	3½	6	8½	14	8	4	11	29	6	7	14	8	11	27½
6 by 5	3½	6½	9½	15	8½	4½	12	31½	6½	7	15	8½	12	30

Vent branch							
Size	X	E	F	G and G′	J	R′	Wt
2	9	4½	11½	7	4½	3	11½
3	10	5¼	12¾	7½	5½	3½	7¾
4	11	6	14	8	6½	4	25
5	12	6½	15	8½	7½	4½	32½
6	13	7	16	9	8½	5	41
3 by 2	9	4¾	11¾	7	5	3	14¾
4 by 2	9	5	12	7	5½	3	17¾
4 by 3	10	5½	13	7½	6	3½	21½
5 by 2	9	5	12	7	6	3	21
5 by 3	10	5½	13	7½	6½	3½	24½
5 by 4	11	6	14	8	7	4	28½
6 by 2	9	5	12	7	6½	3	23½
6 by 3	10	5½	13	7½	7	3½	27½

Vent branch*							
Size	X	E	F	G and G′	J	R′	Wt
6 by 4	11	6	14	8	7½	4	31½
6 by 5	12	6½	15	8½	8	4½	36

Size	Tapped vent branch		
	F	J	Wt
2 by 2	11½	4½	11¼
3 by 2	11¾	5	14¼
4 by 2	12	5½	17½
5 by 2	12	6	20¼
6 by 2	12	6½	23

TABLE 110.—WEIGHTS AND DIMENSIONS OF EXTRA HEAVY CAST-IRON SOIL PIPE FITTINGS. BELL AND SPIGOT

(Dimensions in inches; weights in pounds, see Fig. 183c)

(Weights are A. S. T. M. A 74–18 standard. Dimensions are manufacturer's standard)

Size	E	E′	F	G	X	X′	Wt	E	E′	F	G	H	R	X	X′	Wt
	Wye branch							Combined wye and one-eighth bend								
2	6¾	6¾	11½	4¾	9	4¼	11	6¾	7¾	11½	4¾	3½	3	9	5¼	12
3	8¼	8¼	13¼	5	10½	5½	17	8¼	9¼	13¼	5	4 9/16	3½	10½	6½	18¾
4	9¾	9¾	15	5¼	12	6¾	24	9¾	10¾	15	5¼	5 9/16	4	12	7¾	27
5	11	11	16½	5½	13½	8	31½	11	12	16½	5½	6⅝	4½	13½	9	35
6	12¼	12¼	18	5¾	15	9¼	39½	12¼	13¼	18	5¾	7 11/16	5	15	10¼	44½
3 by 2	7 9/16	7½	11¾	4 3/16	9	5	14	7 9/16	8¼	11¾	4 3/16	4	3	9	5¾	15
4 by 2	8 5/16	8¼	12	3 11/16	9	5¾	17¼	8 5/16	8¾	12	3 11/16	4½	3	9	6¼	18¼
4 by 3	9	9	13½	14½	10½	6½	20½	9	9¾	13½	4½	5 1/16	3½	10½	7	22½
5 by 2	8 13/16	8 15/16	12	3⅜	9	6 7/16	20	8 13/16	9¼	12	3⅜	5	3	9	6¾	21
5 by 3	9½	9 11/16	13½	4	10½	6 15/16	23½	9½	10¼	13½	4	5 9/16	3½	10½	7½	25½
5 by 4	10¼	10 7/16	15	4⅜	12	7 7/16	27½	10¼	11¼	15	4¾	6 1/16	4	12	8¼	30½
6 by 2	9 5/16	9⅝	12	2 11/16	9	7⅛	23	9 5/16	9¾	12	2 11/16	5½	3	9	7¼	24
6 by 3	10	10⅜	13½	3½	10½	7⅝	27	10	10¾	13½	3½	6 1/16	3½	10½	8	29
6 by 4	10¾	11⅛	15	4¼	12	8⅛	31	10¾	11¾	15	4¼	6 9/16	4	12	8¾	34
6 by 5	11 7/16	11⅝	16½	5 1/16	13½	8⅝	35	11 7/16	12½	16½	5 1/16	7⅛	4½	13½	9½	39
	One-half wye branch							Upright wye branch								
2	5¼	5¼	11½	6¼	9	2¾	10¼	6¾	4½	11½	4¾	4½	3	9	6¼	12½
3	6¼	6¼	12¾	6½	10	3½	15½	8¼	5½	13¼	5	5½	3½	10½	7 7/16	19½
4	7¼	7¼	14	6¾	11	4¼	21½	9¾	6½	15	5¼	6½	4	12	8 11/16	28
5	8	8	15	7	12	5	27½	11	7½	16½	5½	7½	4½	13½	9⅞	36½
6	8¾	8¾	16	7¼	13	5¾	34	12¼	8½	18	5¾	8½	5	15	11 1/16	46

3 by 2	5⅝	5¾	11¾	6⅛	9	3¼	13½	7 9/16	5	11¾	4 3/16	5	3	9	6¾	15¾
4 by 2	6⅛	6¼	12	5⅞	9	3¾	16½	8 5/16	5½	12	3 11/16	5½	3	9	7¼	18¾
4 by 3	6⅝	6¾	13	6⅜	10	4	19	9	6	13½	4½	6	3½	10½	7 15/16	23
5 by 2	6⅜	6⅞	12	5⅝	9	4⅜	19½	8 13/16	6	12	3⅜	6	3	9	7¾	21½
5 by 3	6⅞	7¼	13	6⅛	10	4½	22	9½	6½	13½	4	6½	3½	10½	8 7/16	26½
5 by 4	7⅜	7¾	14	6⅝	11	4¾	25	10¼	7	15	4¾	7	4	12	9 3/16	31½
6 by 2	6½	7⅜	12	5½	9	4⅞	22½	9 5/16	6½	12	2 11/16	6½	3	9	8¼	24½
6 by 3	7⅛	7⅞	13	5⅞	10	5⅛	25½	10	7	13½	3½	7	3½	10½	8 15/16	29½
6 by 4	7⅝	8¼	14	6⅜	11	5¼	28½	10¾	7½	15	4¼	7½	4	12	9 11/16	35
6 by 5	8⅛	8½	15	6⅞	12	5½	31	11 7/16	8	16½	5 1/16	8	4½	13½	10⅜	40

Inverted wye branch

2	3½	5⅞	13½	10	11	3⅜	11½
3	4	7⅜	15¼	11¼	12½	4⅝	18
4	4½	8⅞	17	12½	14	5⅞	25½
5	4¾	10⅛	18½	13¾	15½	7⅛	33
6	5	11⅜	20	15	17	8⅜	41½
3 by 2	3¼	6⅝	13¾	10½	11	4⅛	15
4 by 2	3 1/16	7⅜	14	10 15/16	11	4⅞	18¾
4 by 3	3¾	8⅛	15½	11¾	12½	5⅜	22

Inverted wye branch

Size	E	E′	F	G	X	X′	Wt
5 by 2	2⅝	8 1/16	14	11⅜	11	5 9/16	22
5 by 3	3 5/16	8 13/16	15½	12 3/16	12½	6 1/16	25½
5 by 4	4	9 9/16	17	13	14	6 9/16	29½
6 by 2	2 3/16	8¾	14	11 13/16	11	6¼	25½
6 by 3	2⅞	9½	15½	12⅝	12½	6¾	29½
6 by 4	3 9/16	10¼	17	13 7/16	14	7¼	33
6 by 5	4¼	10¾	18½	14¼	15½	7¾	37

For all fittings

Diameter of outlet	2	3	4	5	6
A for all fittings	3	3¼	3½	3½	3½

Diameter of outlet	2	3	4	5	6
C for all fittings	4¼	4 11/16	5 3/16	5⅜	5 9/16

TABLE 111.—WEIGHTS AND DIMENSIONS OF EXTRA HEAVY CAST-IRON SOIL PIPE OFFSETS. BELL AND SPIGOT

(Dimensions in inches; weights in pounds, see Fig. 183*d*)

(Weights are A. S. T. M. A 74–18 standard. Dimensions are manufacturer's standard)

J	F	H	X	Wt	F	H	X	Wt	F	H	X	Wt	F	H	X	Wt
	2-in. straight offset				2-in. one-eighth bend offset				4-in. straight offset				4-in. one-eighth bend offset			
2	10½	2	8	7	10½	2	8	7	12	2	9	13¾	12	2	9	13¾
4	11	1	8½	8	12½	4	10	8¼	14	4	11	16¼	14	4	11	16¼
6	11½	1½	9	9	14½	6	12	9½	14	1½	11	18	16	6	13	18¾
8	12	2	9½	9¾	16½	8	14	10¾	14½	2	11½	19¾	18	8	15	21
10	12½	2½	10	10¾	18½	10	16	12	15	2½	12	21½	20	10	17	23½
12	13	3	10½	11¾	20½	12	18	13¼	15½	3	12½	23½	22	12	19	26
14	13½	3½	11	12¾	22½	14	20	14¾	16	3½	13	25	24	14	21	28½
16	14	4	11½	13¾	24½	16	22	16	16½	4	13½	27	26	16	23	31
18	14½	4½	12	14½	26½	18	24	17¼	17	4½	14	29	28	18	25	33½
20	15	5	12½	15½	28½	20	26	18½	17½	5	14½	30½	30	20	27	36
22	15½	5½	13	16½	30½	22	28	19¾	18	5½	15	32½	32	22	29	38½
24	16	6	13½	17½	32½	24	30	21	18½	6	15½	34	34	24	31	41
	3-in. straight offset				3-in. one-eighth bend offset				5-in. straight offset				5-in. one-eighth bend offset			
2	11¼	2	8½	10¼	11¼	2	8½	10¼	12½	2	9½	17¼	12½	2	9½	17¼
4	12¼	1	9½	12	13¼	4	10½	12	14½	4	11½	20½	14½	4	11½	20½
6	12¾	1½	10	13¼	15¼	6	12½	14	15	1½	12	22½	16½	6	13½	23½
8	13¼	2	10½	14¾	17¼	8	14½	15¾	15½	2	12½	25	18½	8	15½	26½
10	13¾	2½	11	16	19¼	10	16½	17¾	16	2½	13	27	20½	10	17½	29½
12	14¼	3	11½	17½	21¼	12	18½	19½	16½	3	13½	29½	22½	12	19½	32½
14	14¾	3½	12	18¾	23¼	14	20½	21½	17	3½	14	31½	24½	14	21½	35½
16	15¼	4	12½	20½	25¼	16	22½	23½	17½	4	14½	33½	26½	16	23½	38½
18	15¾	4½	13	21½	27¼	18	24½	25½	18	4½	15	36	28½	18	25½	41½
20	16¼	5	13½	23	29¼	20	26½	27	18½	5	15½	38	30½	20	27½	44½
22	16¾	5½	14	24½	31¼	22	28½	29	19	5½	16	40½	32½	22	29½	47½
24	17¼	6	14½	26	33¼	24	30½	31	19½	6	16½	42½	34½	24	31½	50½

	6-in. straight offset				6-in. one-eighth bend offset			
2	13	2⅜	10	21	13	2⅜	10	21
4	15	4	12	24½	15	4	12	24½
6	16	1½	13	28	17	6	14	28
8	16½	2	13½	30½	19	8	16	31½
10	17	2½	14	33	21	10	18	35½
12	17½	3	14½	35½	23	12	20	39
14	18	3½	15	38½	25	14	22	42½
16	18½	4	15½	41	27	16	24	46
18	19	4½	16	43½	29	18	26	49½
20	19½	5	16½	46½	31	20	28	53½
22	20	5½	17	49	33	22	30	57
24	20½	6	17½	51½	35	24	32	60½

For all offsets

Internal diameter	2	3	4	5	6
A	3	3¼	3½	3½	3½
B	3	3½	4	4	4

R = 2 in. M = 3¾ in. N = 4¾ in.

When J = 2 in., C = 3¾ in. and for all other offsets C = 4½ in. When J = 2 in., D = 4¾ in. and for all other offsets D = 5½ in.

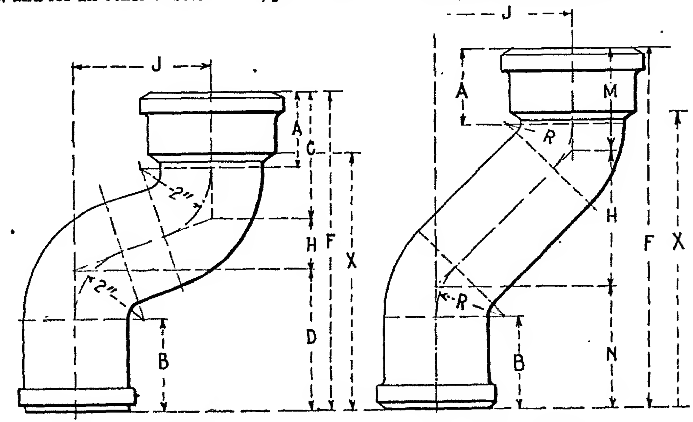


FIG. 183*d*.—Details of cast-iron soil pipe offsets.
(Dimensions in Table 111.)

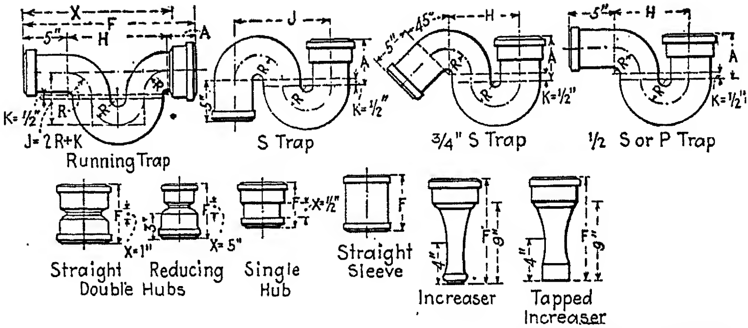


FIG. 183e.—Details of Cast-iron soil pipe fittings, traps, hubs, sleeves, increasers. (Dimensions in Table 112.)

TABLE 112.—WEIGHTS AND DIMENSIONS OF EXTRA HEAVY CAST-IRON SOIL-PIPE FITTINGS. BELL AND SPIGOT

(Manufacturers standard, see Fig. 183e)

Size	Double hub (straight) F	Double hub (straight) Wt	Single hub F	Single hub Wt	Straight sleeve F	Straight sleeve Wt
2	6	5¾	4	4¾	6	6¼
3	6½	8¼	5	6¾	6½	8½
4	7	10¾	5½	9¼	7	11¼
5	7	12¾	5½	10¾	7	13¼
6	7	14¾	5½	12½	7	15¼

Size	Double hub (reducing) F	Double hub (reducing) Wt	Increaser F	Increaser Wt	Tapped increaser F	Tapped increaser Wt
2 by 2					11½	7½
3 by 2	7½	6¼	13¾	8¾	11¾	7½
4 by 2	7½	7	12	10½	12	11

Size	Double hub (reducing) F	Double hub (reducing) Wt	Increaser F	Increaser Wt	Tapped increaser F	Tapped increaser Wt
4 by 3	7¾	8½	12	12		
5 by 2	7½	8	12	12	12	12½
5 by 3	7¾	9¼	12	13½		
5 by 4	8	10¾	12	14¾		
6 by 2	7½	8¾	12	13½	12	14
6 by 3	7¾	10½	12	14¾		
6 by 4	8	11¾	12	16¼		
6 by 5	8	12¾	12	17½		

TABLE 112.—WEIGHTS AND DIMENSIONS OF EXTRA CAST-IRON SOIL-PIPE FITTINGS. BELL AND SPIGOT.—(*Continued*)

Traps													
Size	S ¾ S ½ S	¾ S ½ S	Running S ¾ S ½ S	S	Weights				Running trap				
	A	*H*.	*R*	*J*	*S*	¾ S	½ S	Running	*A*	*F*	*H*	*J*	*X*
2	3½	6	2	8	12	11¼	10¼	11¾	3	16	8	4½	13½
3	4½	7½	2½	10	20	18½	17¼	19	3¼	18¼	10	5½	15½
4	5½	9	3	12	30	27½	25½	27½	3½	20½	12	6½	17½
5	6½	10½	3½	14	40½	37½	34½	37	3½	22½	14	7½	19½
6	7½	12	4	16	53½	49	45	48	3½	24½	16	8½	21½

TABLE 113.—LAYING LENGTH OF EXTRA HEAVY CAST-IRON SOIL-PIPE FITTINGS. BELL AND SPIGOT AND THREADED WITH BELL AND SPIGOT

(Manufacturer's standard. Dimensions in inches)

Diameter of fittings on the run	Tee	Tapped tee	Sanitary tee	Wye	Tapped sanitary wye	½ wye	Inverted wye	Tapped inverted wye	Wyes and one-eighth bend	Upright wye	Vent branch	Tapped vent branch	Reducer	Increaser	Tapped increaser	Single hub	Double hub
2	9	9	9	9	9	9	11	11	9	9	9	9	5	9	9	½	1
3	10	9	10	10½	9	10	12½	11	10½	10½	10	9	5	9	9	½	1
4	11	9	11	12	9	11	14	11	12	12	11	9	5	9	9	½	1
5	12	9	12	13½	9	12	15½	11	13½	13½	12	9	5	9	9	½	1
6	13	9	13	15	9	13	17	11	15	15	13	9	5	9	9	½	1

Laying length of fittings reducing on branch are same as laying lengths of straight fittings.

6. Drainage Fittings. Threaded Cast-iron Fittings.

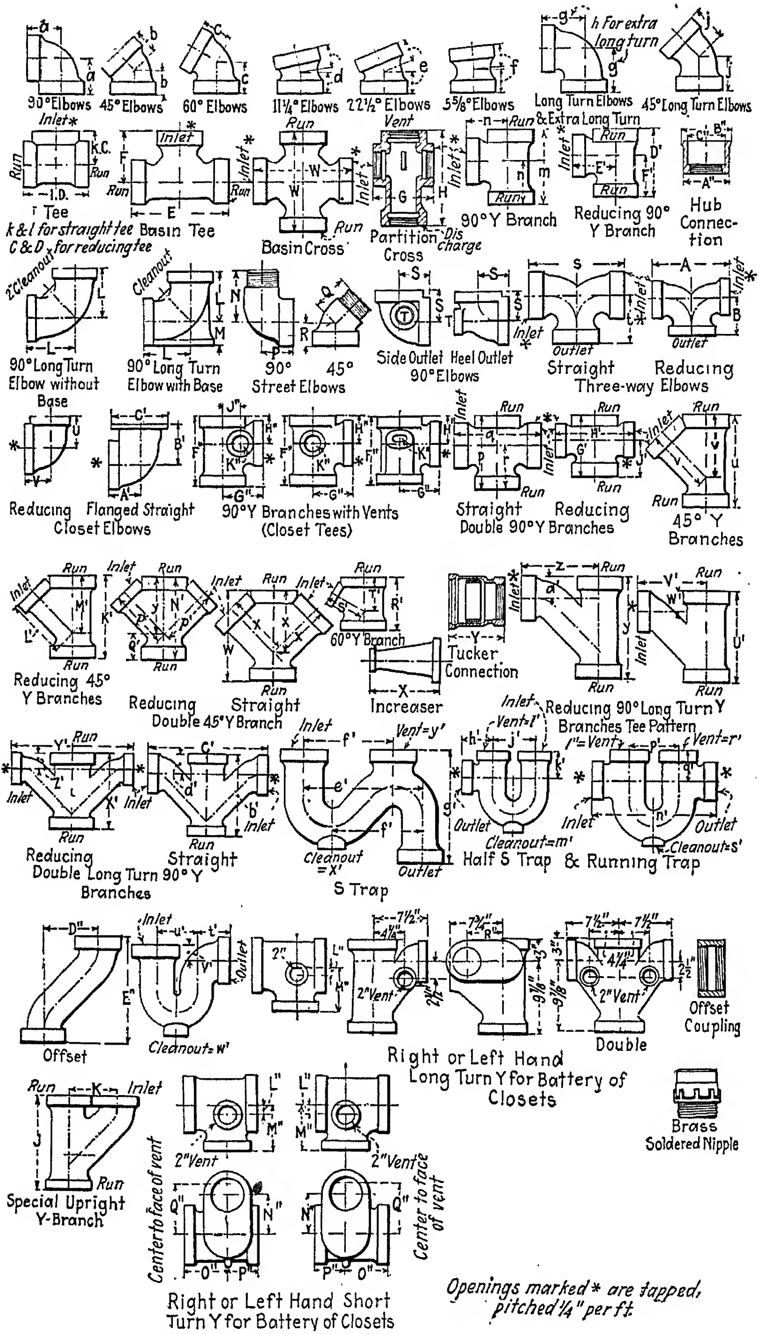


FIG. 184.—Cast-iron drainage fittings. Manufacturer's standard.

TABLE 114.—DIMENSIONS OF DRAINAGE FITTINGS
(Manufacturer's Standard. Subject to slight variation and change, see Fig. 184)

Dimension	1	1¼	1½	2	2½	3	4	5	6	7	8	10	12
a	......	1¾	2 3/16	2⅜	2 13/16	3 3/16	3 3/16	4½	5 3/16	5 13/16	6½	7¾	9
b	......	1 5/16	1 7/16	1¾	2 1/16	2⅜	2¾	3 3/16	3½	3⅞	4 3/16	4⅞	5½
c	......	1 9/16	1¾	2	2½	2⅞	3⅜	3⅞	4 3/16	4½	5⅜	6¼	
d	......	1	1 1/32	1 13/32	1 21/32	1 13/16	2⅛	2⅜	2½	2⅝	2¾	3	
e	......	1⅛	1¼	1 7/16	1¾	2	2 5/16	2⅝	2 15/16	3¼	3 9/16	3⅞	4 3/16
f	......	1	1 5/16	1½	......	1¾	2	2¼	2 5/16	2⅜	2½	2¾	
g	......	2¼	2½	3 1/16	3 11/16	4¼	5 3/16	6⅛	7⅛	8⅛	9	11	13
h	......	3	3½	4									
j	......	1¾	1⅞	2¼	2⅝	2⅞	3 7/16	4⅛	4⅞	5½	6	7½	8¾
k	......	1¾	2 3/16	2 5/16	2 13/16	3 3/16	4	4⅝	5 1/16	5 13/16	6½	7¾	9
l	......	3½	4⅜	4⅝	5⅝	6⅜	8	9¼	10⅜	11⅝	13	15½	18
m	3¼	3¾	4¼	5 3/16	6 5/16	7¼	8¾	10 5/16	11 15/16	13⅝	15 1/16	20	24¼
n	1 15/16	2¼	2½	3 1/16	3 11/16	4¼	5 3/16	6⅛	7⅛	8⅛	9	11⅜	13¾
p	3¼	3¾	4¼	5 3/16	6 5/16	7¼	8¾	10 5/16	11 15/16	13⅝	15 1/16	20	
q	3⅞	4½	5	6⅛	7⅜	8½	10⅜	12¼	14¼	16¼	18	22¾	
r	1 15/16	2¼	2½	3 1/16	3 11/16	4¼	5 3/16	6⅛	7⅛	8⅛	9	11⅜	
s	......	4½	5¼	6¼	7⅜	8⅝	10⅜						
t	......	2¼	2⅝	3⅛	3 11/16	4 5/16	5 3/16						
u	......	5	5½	6 7/16	7⅞	9	10⅞	12 15/16	14¾	16 11/16	18 13/16	20	24¼
v	......	3¼	3⅝	4 5/16	5⅜	6 3/16	7 11/16	9 3/16	10¾	12¼	13 9/16	16⅛	19⅝
w	......	5	5½	6 7/16	7⅞	9	10⅞	12 15/16	14¾	16 11/16	18 13/16	20	
x	......	3¼	3⅝	4 5/16	5⅜	6 3/16	7 11/16	9 3/16	10¾	12¼	13 9/16	16⅛	
y	......	4¾	5⅜	7 1/16	8¼	9 13/16	13¾	15¾	18 11/16	21⅝	24 9/16		
z	......	3⅝	4⅛	5 7/16	6¼	7½	9⅞	12¼	14 9/16	16⅞	19 5/16		

a′	......	1 3/16	1¼	1⅝	2	2 5/16	2⅞	3½	4⅛	4¾	5¼		
b′	......	4¾	5⅜	7 1/16	8¼	9 13/16	13¾	15¾	18 11/16	21⅝	24 9/16		
c′	......	7¼	8¼	10⅞	12½	15	19¾	24½	29⅛	33¾	38⅝		
d′	......	1 3/16	1¼	1⅝	2	2 5/16	2⅞	3½	4⅛	4¾	5¼		
e′	......	....	....	8¼	......	10¾	14⅛	16¾	20¼				
f′	......	....	....	6¼	......	8 1/16	10⅝	12 9/16	15 3/16				
g′	......	....	....	8	......	11¼	13¾	16⅞	19¾				
h′	......	2 5/16	2½	3 1/16	......	4 3/16	5⅛	6 1/16	6 9/16	7¾	8 15/16		
j′	......	3⅛	3⅜	4	......	5⅜	7	8⅜	10⅛	11¼	12⅜		
k′	......	2	2¼	2 9/16	......	3½	4 3/16	4¾	5 7/16	6⅛	6¾		
l′	......	1¼	1½	2	......	3	4	4	4	5	6		
m′	......	¾	1	1	......	1¼	2	2	2	2	3		
n′	......	7¾	8⅜	10⅛	......	13¼	17¼	20½	23¼	26¾	30¼	36¼	41⅞
p′	......	3⅛	3⅜	4	......	5⅜	7	8⅜	10⅛	11¼	12⅜	14¾	17
q′	......	2	2¼	2 9/16	......	3½	4 3/16	4¾	5 7/16	6⅛	6¾	8¼	9½
r′	......	1¼	1½	2	......	3	4	4	4	5	6	6	6
s′	......	¾	1	1	......	1¼	2	2	2	2	3	3	3
t′	......	1 15/16	2⅛	2 9/16	......	3⅜							
u′	......	2	2¼	2¾	......	3¾							
v′	......	¾	⅞	⅞	......	1 3/16							
w′	......	¾	1	1	......	1¼							
x′	......	....	....	1	......	1¼	2	2	2				
y′	......	....	....	2	......	3	4	4	4				

TABLE 115.—DIMENSIONS OF DRAINAGE FITTINGS

(Manufacturer's standard. Subject to slight variation and change, see Fig. 184)

Size	4 by 3	5 by 4	6 by 4	6 by 5
A	9 1/2	11 3/8	12 3/8	13 3/8
B	4 5/16	5 5/16	5 7/16	6 1/4

Size	1 1/2 by 1 1/4	2 by 1 1/2	3 by 2	4 by 2	4 by 3	5 by 2	5 by 3
C	2 5/16	2 1/4	3	3 9/16	3 3/4	4 3/16	4 3/8
D	4 5/8	4 1/8	5 1/2	6	7	6	6 7/8

Size	1 1/4	1 1/2	1 1/2 by 1 1/4	2	2 by 1 1/4
E	4 5/8	5 3/8	5 1/8	7	6 1/4
F	2 5/16	2 11/16	2 9/16	3 1/2	3 1/8

Size	2 by 1 1/2	2 1/2
E	6 1/2	8 1/2
F	3 1/4	4 1/4

Size	1 1/2 by 1 1/4
G	3 1/2
H	5 1/2

Size	2 by 1 1/2	2 1/2 by 1 1/2	2 1/2 by 2	3 by 2	3 by 3	4 by 2	4 by 4
J	5 7/8	5 15/16	7 1/8	9 11/16	9 11/16	7 1/8	11 3/4
K	2 15/16	3 5/16	3 5/8	4 5/8	4 5/8	4 9/16	5 13/16

Size	4
L	6 1/4
M	2 7/8

Size	1 1/4	1 1/2	2
N	2 5/8	2 15/16	3 5/16
P	1 5/8	1 13/16	2 1/8

Size	1 1/4	1 1/2	2
Q	1 7/8	2	2 7/16
R	1 3/16	1 1/4	1 3/4

Size	4
S	3 13/16
T	2

Size	4 by 5
U	4 7/16
V	3 13/16

Size	1 1/4	1 1/2	2	2 by 1 1/2
W	4 5/8	5 3/8	7	6 1/2

Size	2 by 1 1/2	2 1/2 by 2	3 by 2	4 by 2	4 by 3	5 by 2	5 by 3
X	9	9	9	9	9	9	9

Size	5 by 4	6 by 4	6 by 5	8 by 4	8 by 6
X	9	9	9	9	9

Size	2	3	4	5	6	8
Y	4 1/2	4 3/4	7	7	7	7

Size	4
A′	3 13/16
B′	4 5/8
C′	7

Size	1 1/2 by 1 1/4	2 by 1 1/2	2 1/2 by 1 1/2	2 1/2 by 2	3 by 1 1/2	3 by 2	4 by 1 1/2	4 by 2	4 by 2 1/2	4 by 3	3 by 4	5 by 1 1/2	5 by 2	5 by 3
D′	3 7/8	4 5/8	4 7/8	5 1/2	5 1/16	5 11/16	5 1/4	5 13/16	6 5/8	7 3/8	8 5/8	5 9/16	6 1/8	7 3/4
E′	2 1/2	2 15/16	3 1/16	3 5/16	3 5/16	3 5/8	3 13/16	4 1/16	4 7/16	4 3/4	5 3/16	4 3/8	4 5/8	5 1/4
F′	2 3/8	2 11/16	2 13/16	3 1/4	2 15/16	3 5/16	3	3 3/8	3 13/16	4 5/16	5 1/8	3 3/16	3 9/16	4 1/2

Size	5 by 4	6 by 2	6 by 3	6 by 4	6 by 5	8 by 3	8 by 4	8 by 6
D′	9 1/8	6 1/4	7 7/8	9 1/4	10 9/16	11 7/16	11 7/16	15 1/16
E′	5 11/16	5 1/8	5 3/4	6 3/16	6 5/8	7 1/4	7 9/16	8 5/16
F′	5 3/8	3 5/8	4 9/16	5 7/16	6 1/4	7 15/16	7 1/2	9 5/8

Size	1 1/2 by 1 1/4	2 by 1 1/2	2 1/2 by 2	3 by 1 1/2	3 by 2	4 by 2	5 by 3
G′	3 7/8	4 5/8	5 1/2	5 1/16	5 11/16	5 13/16	7 3/4
H′	5	5 7/8	6 5/8	6 5/8	7 1/4	8 1/8	10 1/2
J′	2 3/8	2 11/16	3 1/4	2 15/16	3 5/16	3 3/8	4 1/2

Size	5 by 4	6 by 2	6 by 4	6 by 5	8 by 6
G′	9 1/8	6 1/4	9 1/4	10 9/16	15 1/16
H′	11 3/8	10 1/4	12 3/8	13 1/4	16 5/8
J′	5 3/8	3 5/8	5 7/16	6 1/4	9 5/8

Size	2 by 1 1/2	2 1/2 by 1 1/2	2 1/2 by 2	3 by 1 1/2	3 by 2	3 by 2 1/2	4 by 1 1/2	4 by 2	4 by 3	5 by 2
K′	5 7/8	6 7/16	7 1/16	6 5/8	7 3/8	8	7 3/16	7 11/16	9 1/4	8 1/4
L′	4 1/8	4 5/8	5 1/8	5 1/16	5 3/8	5 13/16	6 1/16	6 5/16	7 3/16	7 3/16
M′	4 1/16	4 9/16	4 15/16	4 15/16	5 5/16	5 11/16	5 3/4	6	6 7/8	6 7/8

Size	5 by 3	5 by 4	6 by 2	6 by 3	6 by 4	6 by 5	7 by 3	7 by 4	7 by 5	7 by 6	8 by 4	8 by 6	10 by 4	10 by 6	12 by 6	14 by 6
K′	9 13/16	11 3/8	8 7/16	10	11 7/8	13	10	11 7/16	16 11/16	16 11/16	11 7/16	14 15/16	14	15 1/2	18	19 1/2
L′	7 7/8	8 1/2	8 1/16	8 3/4	9 3/8	10	9 5/8	10 1/4	10 15/16	11 9/16	11	12 3/8	12 7/8	14 1/4	15 3/4	17 3/4
M′	7 5/8	8 7/16	7 9/16	8 5/16	9 1/16	9 13/16	8 7/8	9 11/16	10 1/2	11 3/8	10 7/16	11 7/8	11 1/2	13 1/2	14 1/4	16 3/8

Size	2 by 1 1/2	2 1/2 by 1 1/2	3 by 1 1/2	3 by 2	4 by 2	4 by 3	5 by 2	5 by 3	5 by 4	6 by 2	6 by 4	8 by 4	8 by 6
N′	5 7/8	6 7/16	6 5/8	7 3/8	7 11/16	9 1/4	8 1/4	9 13/16	11 3/8	8 7/16	11 7/8	11 7/16	14 15/16
P′	4 1/8	4 5/8	5 1/16	5 3/8	6 5/16	7 3/16	7 3/16	7 7/8	8 1/2	8 1/16	9 3/8	11	12 3/8
Q′	4 1/16	4 9/16	4 15/16	5 5/16	6	6 7/8	6 7/8	7 5/8	8 7/16	7 9/16	9 1/16	10 7/16	11 7/8

Size	1 1/2 by 1 1/2	2 by 2
R′	4 5/8	5 1/2
S′	2 5/8	3 1/4
T′	2 5/8	3 1/4

Size	2 by 1 1/2	3 by 2	4 by 4	4 by 2	5 by 5	5 by 3	6 by 6	8 by 4
R′	4 15/16	6 7/16	9 3/8	6 11/16	11 1/8	8 1/2	13	11 7/16
S′	3 1/16	4 1/8	5 3/4	4 3/4	6 3/4	6	7 7/8	8 9/16
T′	2 15/16	3 15/16	5 3/4	4 5/16	6 3/4	5 9/16	7 7/8	7 3/8

Size	1 1/4 by 1	1 1/2 by 1	1 1/2 by 1 1/4	2 by 1 1/2	2 1/2 by 1 1/2	2 1/2 by 2	3 by 1 1/2
U′	4 1/4	4 1/2	5 1/8	5 3/4	5 3/4	7 3/8	5 15/16
V′	3 1/2	3 5/8	3 7/8	4 3/8	4 9/16	5 3/4	5
W′	1	1	1 3/16	1 5/16	1 5/16	1 5/8	1 5/16

Size	3 by 2	4 by 1 1/2	4 by 2	4 by 2 1/2	4 by 3	5 by 1 1/2	5 by 2	5 by 3	5 by 4	6 by 2	6 by 3	6 by 4	6 by 5	7 by 3	7 by 4	8 by 3
U′	7 9/16	6 1/16	7 11/16	8 5/8	10	6 5/16	7 3/4	10 1/4	13	7 15/16	10 3/8	13 1/16	16 1/16	10 7/8	13 5/16	10 5/8
V′	6 1/16	5 7/16	6 5/8	7 1/16	8 1/16	6	7 1/8	8 5/8	10 7/16	7 3/4	9 1/8	11	12 13/16	9 11/16	11 5/8	10 1/4
W′	1 5/8	1 5/16	1 5/8	2	2 3/8	1 3/8	1 5/8	2 3/8	2 7/8	1 5/8	2 5/16	2 7/8	3 1/2	2 5/8	2 7/8	2 5/16

Size	8 by 4	10 by 4	12 by 5
U′	13 3/8	14	17
V′	12	13	15 1/2
W′	2 15/16	3	4

Size	1 1/4 by 1	1 1/2 by 1	1 1/2 by 1 1/4	2 by 1 1/2	2 1/2 by 1 1/2	3 by 1 1/2	3 by 2	4 by 2	4 by 3	5 by 4	6 by 2	6 by 4	6 by 5
X′	4 1/4	4 1/2	5 1/8	5 3/4	5 3/4	5 15/16	7 9/16	7 11/16	10	13	7 15/16	13 1/16	16 1/16
Y′	7	7 1/4	7 3/4	8 3/4	9 1/8	10	12 1/8	13 1/4	16 1/8	20 7/8	15 1/2	22	22 5/8
Z′	1	1	1 3/16	1 5/16	1 5/16	1 5/16	1 5/8	1 5/8	2 3/8	2 7/8	1 5/8	2 7/8	3 1/2

Size	2	3	4	5	6
A″	3 1/2	4 9/16	5 5/8	6 11/16	7 3/4
B″	3 13/16	4 15/16	6	7 1/16	8 3/16
C″	3	4 1/8	5 1/8	6	7 1/8

Size	2	2	2	2	3	3	3	3	4	4	4	4	4	5	5	5	5	6	6	6	6
D″	4	6	8	10	4	6	8	10	4	6	8	10	12	6	8	10	12	6	8	10	12
E″	7 1/2	9 1/2	11 1/2	13 1/2	8 3/4	10 3/4	12 3/4	14 3/4	9 3/4	11 3/4	13 3/4	15 3/4	17 3/4	12 5/8	14 5/8	16 5/8	18 5/8	13 5/8	15 5/8	17 5/8	19 5/8

Size	F″	G″	H″	J″	K″
4 in.	8 3/4	5 3/16	3 9/16	2 5/16	2

TABLE. 115.—DIMENSIONS OF DRAINAGE FITTINGS.—(*Continued*)

Tapping number	Size 4 by 4, in inches							Size 5 by 4, in inches						
	L″	M″	N″	O″	P″	Q″	R″	L″	M″	N″	O″	P″	Q″	R″
1	0	5¼	2⅝	5¼	3½	3	5¼	1¼	5¾	4⅞	5⅜	3¾	6¼	5¼
2	0	5¼	2¼	5¼	3½	3	4⅞	1¼	5¾	4½	5⅜	3¾	6¼	4⅞
3	0	5¼	1⅞	5¼	3½	3	4½	1¼	5¾	4⅛	5⅜	3¾	6¼	4½
4	0	5¼	1½	5¼	3½	3	4⅛	1¼	5¾	3¾	5⅜	3¾	6¼	4⅛
5	0	5¼	1⅛	5¼	3½	3	3¾	1¼	5¾	3⅜	5⅜	3¾	6¼	3¾
6	0	5¼	¾	5¼	3½	3	3⅜	1¼	5¾	3	5⅜	3¾	6¼	3⅜
7							3	1¼	5¾	2⅝	5⅜	3¾	6¼	3
8							2⅝	1¼	5¾	2¼	5⅜	3¾	6¼	2⅝
9							2¼	1¼	5¾	1⅞	5⅜	3¾	6¼	2¼
10							1⅞	1¼	5¾	1½	5⅜	3¾	6¼	1⅞
11							1½	1¼	5¾	1⅛	5⅜	3¾	6¼	1½
12							1⅛	1¼	5¾	¾	5⅜	3¾	6¼	1⅛

7. **Wrought Pipe and Fittings.**—Wrought-iron and steel. All wrought pipe and fittings used for permanent installation should be galvanized.

TABLE 116.—COMPOSITION OF STEEL FOR WELDED TUBULAR PRODUCTS (National Tube Company)

Material	Average chemical analysis				Average physical properties			
	Copper, per cent	Manganese, per cent	Sulphur, per cent	Phosphorus, per cent	Yield point, pounds per square inch	Tensile strength, pounds per square inch	Per cent elongation in 8 in.	Reduction in area, per cent
Bessemer........	0.07	0.35	0.050	0.100	36,000	58,000	22	55
Open-hearth.....	0.10	0.40	0.350	0.020	33,000	52,000	25	60

TABLE 117.—DIMENSIONS OF STANDARD WROUGHT-IRON OR STEEL PIPE
(Any length up to 22 ft. available)

Nominal size, inches	Actual diameter, inches		Thickness, inches	Circumference, inches		Transverse areas, square inches			Length of pipe in feet, per square foot of		Nominal weight in pounds per foot of		Length of pipe containing 1 cu. ft.	Number of threads per inch	Length of thread, inches (see A Fig. 185)	Working pressure pounds per square inch
	External O. D.	Internal		External	Internal	External	Internal	Metal	External surface	Internal surface	Plain ends	Threaded and coupled				
1/8*	0.405	0.269	0.068	1.272	0.845	0.129	0.057	0.072	9.431	14.199	0.244	0.245	2,533.775	27	3/8	1,679
1/4*	0.540	0.364	0.088	1.696	1.144	0.229	0.104	0.125	7.073	10.493	0.424	0.425	1,383.789	18	9/16	1,629
3/8*	0.675	0.493	0.091	2.121	1.549	0.358	0.191	0.167	5.658	7.747	0.567	0.568	754.360	18	9/16	1,348
1/2*	0.840	0.622	0.109	2.639	1.954	0.554	0.304	0.250	4.547	6.141	0.850	0.852	473.906	14	3/4	1,298
3/4*	1.050	0.824	0.113	3.299	2.589	0.866	0.533	0.333	3.637	4.635	1.130	1.134	270.034	14	3/4	1,076
1*	1.315	1.049	0.133	4.131	3.296	1.358	0.864	0.494	2.904	3.641	1.678	1.684	166.618	11 1/2	15/16	1,011
1 1/4*	1.660	1.380	0.140	5.215	4.335	2.164	1.495	0.669	2.301	2.767	2.272	2.281	96.275	11 1/2	15/16	843
1 1/2*	1.900	1.610	0.145	5.969	5.058	2.835	2.036	0.799	2.010	2.372	2.717	2.731	70.733	11 1/2	1	763
2*	2.375	2.067	0.154	7.461	6.494	4.430	3.355	1.075	1.608	1.847	3.652	3.678	42.913	11 1/2	1 1/8	648
2 1/2*	2.875	2.469	0.203	9.032	7.757	6.492	4.788	1.704	1.328	1.547	5.793	5.819	30.077	8	1 1/2	706
3*	3.500	3.068	0.216	10.996	9.638	9.621	7.393	2.228	1.091	1.245	7.575	7.616	19.479	8	1 9/16	617
3 1/2*	4.000	3.548	0.226	12.566	11.146	12.566	9.886	2.680	0.954	1.076	9.109	9.202	14.565	8	1 5/8	701
4*	4.500	4.026	0.237	14.137	12.648	15.904	12.730	3.174	0.848	0.948	10.790	10.889	11.312	8	1 11/16	658
4 1/2	5.000	4.506	0.247	15.708	14.156	19.635	15.947	3.688	0.763	0.847	12.538	12.642	9.030	8	1 3/4	618
5*	5.563	5.047	0.258	17.477	15.856	24.306	20.006	4.300	0.686	0.756	14.617	14.810	7.198	8	1 13/16	579
6*	6.625	6.065	0.280	20.813	19.054	34.472	28.891	5.581	0.576	0.629	18.974	19.185	4.984	8	1 7/8	528
7	7.625	7.023	0.301	23.955	22.063	45.664	38.738	6.926	0.500	0.543	23.544	23.269	3.717	8	2	493
8	8.625	8.071	0.277	27.096	25.356	58.426	51.161	7.265	0.442	0.473	24.696	25.000	2.815	8	2 1/16	401
8*	8.625	7.981	0.322	27.096	25.073	58.426	50.027	8.399	0.442	0.478	28.554	28.809	2.878	8	......	466
9*	9.625	8.941	0.342	30.238	28.089	72.760	62.786	9.974	0.396	0.427	33.907	34.188	2.294	8	2 3/16	444
10	10.750	10.192	0.279	33.772	32.019	90.763	81.585	9.178	0.355	0.374	31.201	32.000	1.765	8	2 5/16	324
10	10.750	10.136	0.307	33.772	31.843	90.763	80.691	10.072	0.355	0.376	34.240	35.000	1.785	8	......	357
10*	10.750	10.020	0.365	33.772	31.479	90.763	78.855	11.908	0.355	0.381	40.483	41.132	1.826	8	......	424
11	11.750	11.000	0.375	36.914	34.558	108.434	95.033	13.401	0.325	0.347	45.557	46.247	1.515	8	2 3/8	399
12	12.750	12.090	0.330	40.055	37.982	127.676	114.800	12.876	0.299	0.315	43.773	45.000	1.254	8	2 1/2	324

12*	12.750	12.000	0.375	40.055	37.699	127.676	113.097	14.579	0.299	0.318	49.562	50.706	1.273	8	....	368
14	14	13.625	0.375	......	......	......	......	......	......	......	......	......	......	......	2⅝	335
15	15	14.625	0.375	......	......	......	......	......	......	......	......	......	......	......	2¾	312
16	16	15.625	0.375	......	......	......	......	......	......	......	......	......	......	......	2 13/16	293
17	17	16.607	0.393	......	......	......	......	......	......	......	......	......	......	......	2 15/16	289
18	18	17.591	0.409	......	......	......	......	......	......	......	......	......	......	......	3	284
20	20	19.591	0.409	......	......	......	......	......	......	......	......	......	......	......	3¼	256

* Recommended Sep. 1, 1926 by Division of Simplified Practice, U. S. Department of Commerce. These Standards are in agreement with A. S. T. M. Standards A 72–21.

Note: In computing bursting pressures formula used was $BP = \frac{2T \times TS}{(8)OD}$.

BP = working pressure pounds per square inch. T = Thickness of wall, inches.
TS = tensile strength of metal in pounds per square inch.
OD = outside diameter in inches.
TS = 40,000 up to 3 in.
= 50,000 above 3 in.

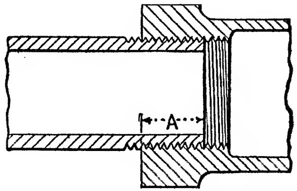


FIG. 185.—Length of thread on threaded joint.
(Dimensions in next to last column of Table 117.)

TABLE 118.—DIMENSIONS OF EXTRA STRONG AND DOUBLE EXTRA STRONG WROUGHT-IRON OR STEEL PIPE
(Manufacturer's standards)

Nominal size, inches	Actual diameter, inches		Thickness, inches	Circumference, inches		Transverse areas, square inches			Length of pipe in feet, per square foot of		Nominal weight in pounds per foot of plain ends	Length in feet of pipe containing 1 cu. ft.	Working pressure, pounds per square inch
	External O. D.	Internal		External	Internal	External	Internal	Metal	External surface	Internal surface			
						Extra strong							
⅛*	0.405	0.215	0.095	1.272	0.675	0.129	0.036	0.093	9.431	17.766	0.314	3,966.4	2,340
¼*	0.540	0.302	0.119	1.696	0.949	0.229	0.072	0.157	7.703	12.648	0.535	2,010.3	2,200
⅜*	0.675	0.423	0.126	2.121	1.329	0.358	0.141	0.217	5.658	9.030	0.738	1,024.7	1,870
½*	0.840	0.546	0.147	2.639	1.715	0.554	0.244	0.320	4.547	6.995	1.087	615.0	1,750
¾*	1.050	0.742	0.154	3.299	2.331	0.866	0.433	0.433	3.637	5.147	1.473	333.0	1,468
1*	1.315	0.957	0.179	4.131	3.007	1.358	0.719	0.639	2.904	3.991	2.171	200.2	1,362
1¼*	1.660	1.278	0.191	5.215	4.015	2.164	1.283	0.881	2.301	2.988	2.996	112.3	1,150
1½*	1.900	1.500	0.200	5.969	4.712	2.835	1.727	1.068	2.010	2.546	3.631	81.5	1,054
2*	2.375	1.939	0.218	7.461	6.092	4.430	2.953	1.477	1.608	1.969	5.022	48.8	918
2½*	2.875	2.323	0.276	9.032	7.298	6.492	4.238	2.254	1.328	1.644	7.661	34.0	960
3*	3.500	2.900	0.300	10.996	9.111	9.621	6.605	3.016	1.091	1.317	10.252	21.8	856
3½*	4.000	3.364	0.318	12.566	10.568	12.566	8.888	3.678	0.954	1.135	12.505	16.2	993
4*	4.500	3.826	0.337	14.137	12.020	15.904	11.497	4.407	0.848	0.998	14.983	12.5	937
4½	5.000	4.290	0.355	15.708	13.477	19.635	14.455	5.180	0.763	0.890	17.611	10.0	888
5*	5.563	4.813	0.375	17.477	15.120	24.306	18.194	6.112	0.686	0.793	20.778	7.9	842
6*	6.625	5.761	0.432	20.813	18.099	34.472	26.067	8.405	0.576	0.663	28.573	5.5	815
7	7.625	6.652	0.500	23.955	20.813	45.664	34.472	11.192	0.500	0.576	38.048	4.18	820
8*	8.625	7.625	0.500	27.096	23.955	58.426	45.663	12.763	0.442	0.500	43.388	3.15	725
9	9.625	8.625	0.500	30.238	27.096	72.760	58.426	14.334	0.396	0.442	48.728	2.46	650
10*	10.750	9.750	0.500	33.772	30.631	90.763	74.662	16.101	0.355	0.391	54.735	1.93	582

11	11.750	10.750	0.500	36.914	33.772	108.434	90.763	17.671	0.325	0.355	60.075	1.59	532
12*	12.750	11.750	0.500	40.055	36.914	127.676	108.434	19.242	0.299	0.325	65.415	1.33	490
Double extra strong													
½*	0.840	0.252	0.294	2.639	0.792	0.554	0.050	0.504	4.547	15.157	1.714	2,837.2	3,500
¾*	1.050	0.434	0.308	3.299	1.363	0.866	0.143	0.718	3.637	8.801	2.440	973.4	2,930
1*	1.315	0.599	0.358	4.131	1.882	1.358	0.282	1.076	2.904	6.376	3.659	511.0	2,720
1¼*	1.660	0.896	0.382	5.215	2.815	2.164	0.630	1.534	2.301	4.263	5.214	228.4	2,300
1½*	1.900	1.100	0.400	5.969	3.456	2.835	0.950	1.885	2.010	3.472	6.408	151.5	2,104
2*	2.375	1.503	0.436	7.461	4.722	4.430	1.774	2.656	1.608	2.541	9.029	81.2	1,835
2½*	2.875	1.771	0.552	9.032	5.564	6.492	2.461	4.028	1.328	2.153	13.605	58.5	1,920
3*	3.500	2.300	0.600	10.966	7.226	9.621	4.155	5.436	1.031	1.660	18.583	34.7	1,716
3½*	4.000	2.728	0.636	12.566	8.570	12.566	5.845	6.721	0.954	1.400	22.850	24.6	1,990
4*	4.500	3.152	0.674	14.137	9.902	15.904	7.803	8.101	0.848	1.211	27.541	18.5	1,871
4½	5.000	3.580	0.710	15.708	11.247	19.635	10.066	9.569	0.763	1.066	32.530	14.3	1,776
5*	5.563	4.063	0.750	17.477	12.764	24.306	12.966	11.340	0.686	0.940	38.552	11.1	1,682
6*	6.625	4.897	0.864	20.813	15.384	34.472	18.835	15.637	0.576	0.780	53.160	7.6	1,632
7	7.625	5.875	0.875	23.955	18.457	45.664	27.109	18.555	0.500	0.650	63.079	5.31	1,435
8*	8.625	6.875	0.875	27.096	21.598	58.426	37.122	21.304	0.442	0.555	72.424	3.88	1,268

Threads same as for standard pipe of same nominal size.
Bursting pressure computed as in Table 117.
* Recommended Sep. 1, 1926 by Division of Simplified Practice, U. S. Department of Commerce.

TABLE 119.—DIMENSIONS OF STANDARD COUPLINGS

Size of pipe, inches	Nominal O. D. of coupling, inches	Length of coupling, inches	Weight of coupling, pounds	Size of pipe, inches	Nominal O. D. of coupling, inches	Length of coupling, inches	Weight of coupling, pounds	Size of pipe, inches	Nominal O. D. of coupling, inches	Length of coupling, inches	Weight of coupling, pounds
1/8	19/32	15/16	0.03	1 1/2	2 15/16	2 5/16	0.81	5	6 1/4	4 1/8	8.50
1/4	3/4	1 1/32	0.07	2	2 23/32	2 9/16	1.18	6	7 9/32	4 1/8	9.70
3/8	29/32	1 5/32	0.11	2 1/2	3 5/16	2 7/8	1.70	7	8 9/32	4 1/8	11.10
1/2	1 1/16	1 5/16	0.15	3	3 15/16	3 1/16	2.45	8	9 1/4	4 5/8	13.60
3/4	1 11/32	1 9/16	0.25	3 1/2	4 7/16	3 7/16	3.40	9	10 5/16	5 1/8	17.40
1	1 5/8	1 13/16	0.42	4	4 15/16	3 7/16	3.50	10	11 5/8	6 1/8	31.10
1 1/4	1 31/32	2 1/16	0.60	4 1/2	5 17/32	3 5/8	4.70	12	13 7/8	6 1/8	44.20
Extra heavy, or hydraulic couplings											
3/8	0.95	1 1/2	0.23	1 1/4	2.07	2 5/8	0.90	3	4.00	3 11/16	3.46
1/2	1.13	1 7/8	0.28	1 1/2	2.31	2 7/8	1.35	3 1/2	4.63	4 1/4	5.25
3/4	1.44	2 1/8	0.50	2	2.81	3 1/8	1.80	4	5.13	4 1/4	6.80
1	1.63	2 3/8	0.56	2 1/2	3.31	3 1/2	2.40				
Double extra heavy, or hydraulic couplings											
3/4	1.66	1 7/8	0.70	1 1/4	2.22	2 7/8	1.50	2	3.19	3 3/8	3.55
1	1.90	2 5/8	1.12	1 1/2	2.44	3 1/8	1.88	2 1/2	3.62	3 5/8	4.50

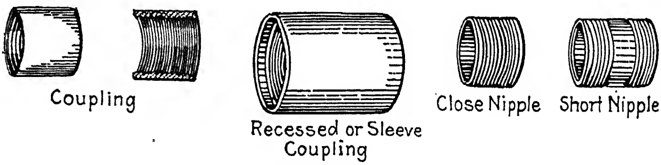


FIG. 186.—Couplings and nipples

8. Malleable-iron Fittings.

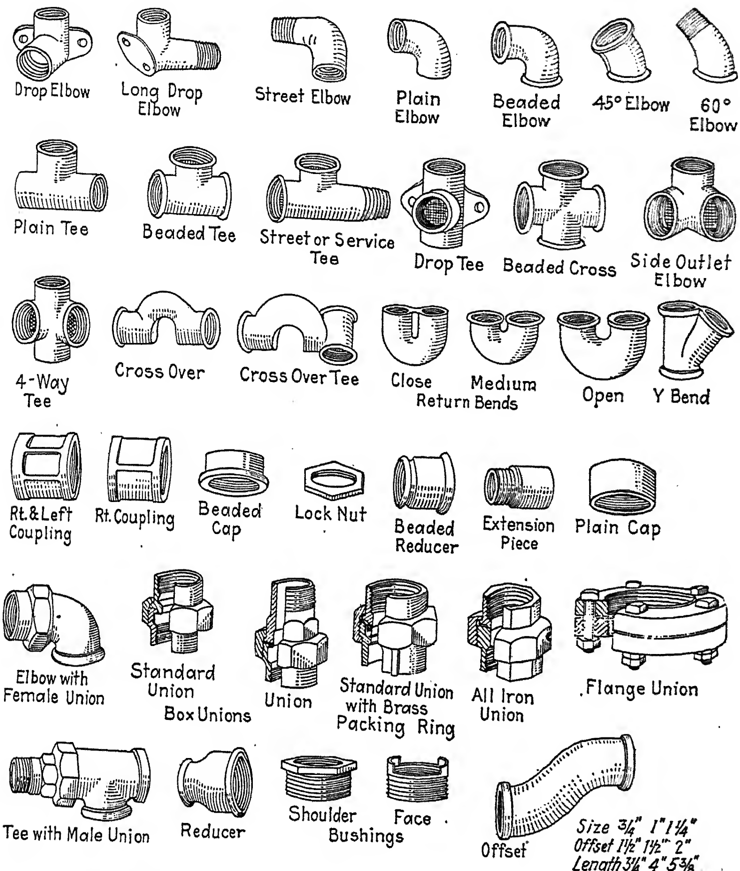


FIG. 187a.—Malleable-iron fittings for threaded wrought pipe. Manufacturer's standard.

TABLE 120.—DIMENSIONS, IN INCHES, OF MALLEABLE-IRON THREADED FITTINGS
(Manufacturer's standard, see Fig. 187b)

Dimension on Fig. 187b	Ells, tees, crosses, wyes, etc. — Nominal internal diameter, inches															
	1/8	1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2	5	6
A	1 1/16	1 3/16	1 5/16	1 1/8	1 5/16	1 7/16	1 3/4	1 15/16	2 1/4	2 11/16	3 1/8	3 7/16	3 3/4	4 1/16	4 7/16	5 1/8
B	.....	3/4	1 3/16	7/8	1	1 1/8	1 5/16	1 7/16	1 11/16	1 15/16	2 3/16	2 3/8	2 5/8	2 13/16	3 1/16	3 7/16
C	.....	.....	2 1/8	2 1/2	2 7/8	3 7/16	4 1/16	4 1/2	5 7/16	6 1/4	7 1/4	.....	8 7/8			
D	.....	.....	1 7/16	1 11/16	2	2 7/16	2 15/16	3 5/16	4 1/16	4 11/16	5 9/16	.....	6 15/16			
E	.....	1	1 1/8	1 1/4	1 7/16	1 11/16	2 1/16	2 5/16	2 13/16	3 1/4	3 11/16	4	4 3/8			
F	17/32	5/8	3/4	7/8	1 1/16	1 3/16	1 1/4	1 5/16	1 7/16	1 5/8	1 3/4	1 15/16	2	.....	2 5/16	2 9/16
G	.....	1 1/16	1 3/16	1 5/16	1 1/2	1 11/16	1 15/16	2 1/8	2 1/2	2 7/8	3 3/16					
H	1 1/8	1 5/16	1 7/16	1 5/8	1 7/8	2 1/8	2 1/2	2 11/16	3 3/16	3 13/16	4 1/2	.....	5 11/16			
K	.....	15/16	1 1/16	1 3/16	1 5/16	1 1/2	1 11/16	1 7/8	2 1/4	.....	3	.....	3 3/4			
L	.....	5/8	11/16	13/16	15/16	1 1/16	1 1/4	1 3/8	1 11/16	.....	2 1/8	.....	2 1/2			

	Malleable-iron unions — Nominal size, inches															
	1/8	1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4	1 by 3/8	1 by 1/2	1 by 3/4
M	.....	13/16	15/16	1 1/8	1 5/16	1 7/16	1 3/4	1 15/16	2 1/4	2 11/16	3 1/8	.....	.....	1 3/16	1 1/4	1 5/16
N	.....	13/16	15/16	1 1/8	1 5/16	1 7/16	1 3/4	1 15/16	2 1/4	2 11/16	3 1/8	.....	.....	1 5/16	1 5/16	1 3/8
O	.....	3/4	13/16	7/8	1	1 1/8	1 5/16	1 7/16	1 11/16							
P	.....	1 13/16	2 1/16	2 5/16	2 5/8	3	3 7/16	3 13/16	4 3/8	4 7/8	5 5/8	.....	.....	2 5/8	2 11/16	2 13/16
Q	.....	2 7/16	2 3/4	3 1/16	3 1/2	3 15/16	4 7/16	4 3/4	5 3/8	6	6 15/16	.....	.....	3 9/16	3 5/8	3 3/4
R	.....	1 9/16	1 11/16	1 7/8	2 1/8	2 7/16	2 3/4	3 1/16	3 1/2							
S	.....	2 3/16	2 3/8	2 11/16	3	3 3/8	3 3/4	4	4 1/2							
T	1 1/2	1 5/8	1 3/4	1 7/8	2 1/8	2 3/8	2 5/8	2 15/16	3 1/4	3 9/16	3 15/16	4 5/16	4 5/8			
U	.....	2 1/4	2 7/16	2 11/16	3 1/16	3 5/16	3 11/16	4	4 5/16	4 11/16	5 5/16					
V	.....	3/4	13/16	7/8	15/16	1 1/16	1 3/16	1 5/16	1 1/2	1 5/8	1 13/16	2	2 1/4			

Dimensions of return bends																
Center line to Center line	close	.....	.....	1	1 1/4	1 1/2	1 3/4	2 3/16	2 5/8							
	medium	.....	.....	1 1/4	1 1/2	1 7/8	2 1/4	2 1/2	3							
	open	.....	.....	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2	5					

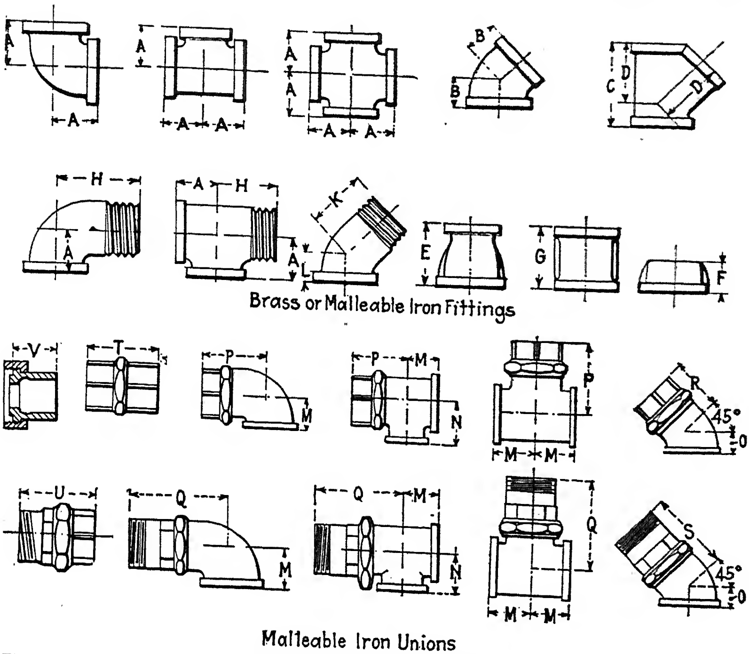


FIG. 187b.—Dimensions of malleable iron and fittings for threaded wrought pipe.

9. Sheet Metal and Wire Gages and Weights.

Sheet copper and brass used for ordinary purposes should not be lighter than No. 18 B. & S. gage except that for local and interior ventilating pipes it should not be lighter than No. 27 B. & S. gage. Galvanized sheet iron should have thicknesses as follows:

Pipe Size, Inches	B. & S. Gage
2–12	26
13–20	24
21–26	22

TABLE 121.—STANDARD GAGES IN INCHES AND APPROXIMATE WEIGHTS OF SHEET METAL IN POUNDS PER SQUARE FOOT

Gage number	Birmingham (B.W.G.) Stubbs iron wire	Brown & Sharp (B. & S.) American	1884 British Imperial	American Steel and Wire Company	Trenton Iron Company	Stubbs steel wire	Old English, London	1893 U. S. plate iron and steel standard	Weights of metal, pounds per square foot United States standard[2]				
									Iron	Steel	Zinc	Copper	Lead
07[1]	.....	....	0.500	0.49	......	.....	....	0.500	20	20.4	18.00	22.63	29.4
06[1]	.....	....	0.464	0.46	......	.....	....	0.46875	18.75	19.125	16.87	21.25	27.55
05[1]	.....	....	0.432	0.43	0.45	.....	....	0.4375	17.50	17.85	15.75	19.85	25.75
04[1]	0.454	0.46	0.400	0.3938	0.40	.....	0.454	0.40625	16.25	16.575	14.62	18.42	23.87
03[1]	0.425	0.40964	0.372	0.3625	0.36	.....	0.425	0.375	15	15.3	13.5	17	22.05
02[1]	0.380	0.3648	0.348	0.3310	0.33	.....	0.380	0.34375	13.75	14.025	12.37	15.59	20.22
0	0.340	0.32486	0.324	0.3065	0.305	.....	0.340	0.3125	12.50	12.75	11.25	14.18	18.38
1	0.300	0.2893	0.300	0.2830	0.285	0.227	0.300	0.28125	11.25	11.475	10.12	12.75	16.54
2	0.284	0.25763	0.276	0.2625	0.265	0.219	0.284	0.265625	10.625	10.8375	9.56	12.06	15.62
3	0.259	0.22942	0.252	0.2437	0.245	0.212	0.259	0.25	10.0	10.2	9.00	11.33	14.70
4	0.238	0.20431	0.232	0.2253	0.225	0.207	0.238	0.234375	9.375	9.5625	8.437	10.62	13.79
5	0.220	0.18194	0.212	0.2070	0.205	0.204	0.220	0.21875	8.75	8.925	7.875	9.91	12.87
6	0.203	0.16202	0.192	0.1920	0.190	0.201	0.203	0.203125	8.125	8.2875	7.3125	9.21	11.93
7	0.180	0.14428	0.176	0.1770	0.175	0.199	0.180	0.1875	7.5	7.65	6.75	8.5	11.02
8	0.165	0.12849	0.160	0.1620	0.160	0.197	0.165	0.171875	6.875	7.0125	6.1875	7.79	10.01
9	0.148	0.11443	0.144	0.1483	0.145	0.194	0.148	0.15625	6.25	6.375	5.625	7.08	9.19
10	0.134	0.10189	0.128	0.1350	0.130	0.191	0.134	0.140625	5.625	5.7375	5.0625	6.37	8.27
11	0.120	0.090742	0.116	0.1205	0.1175	0.188	0.120	0.125	5	5.1	4.5	5.66	7.35
12	0.109	0.080808	0.104	0.1055	0.1050	0.185	0.109	0.109375	4.375	4.4625	3.9375	4.96	6.44
13	0.095	0.071961	0.092	0.0915	0.0925	0.182	0.095	0.09375	3.75	3.825	3.375	4.25	5.51
14	0.083	0.064084	0.080	0.0800	0.0800	0.180	0.083	0.078125	3.125	3.1875	2.8125	3.54	4.59
15	0.072	0.057068	0.072	0.0720	0.0700	0.178	0.072	0.0703125	2.8125	2.86875	2.53125	3.185	4.13
16	0.065	0.05082	0.064	0.0625	0.0610	0.175	0.065	0.0625	2.5	2.55	2.25	2.835	3.675
17	0.058	0.045257	0.056	0.0540	0.0525	0.172	0.058	0.05625	2.25	2.295	2.025	2.55	3.305
18	0.049	0.040303	0.048	0.0475	0.0450	0.168	0.049	0.05	2	2.04	1.8	2.265	2.94
19	0.042	0.03589	0.040	0.0410	0.0400	0.164	0.040	0.04375	1.75	1.785	1.575	1.982	2.575
20	0.035	0.031961	0.036	0.0348	0.0350	0.161	0.035	0.0375	1.50	1.53	1.35	1.700	2.205
21	0.032	0.028462	0.032	0.03175	0.0310	0.157	0.0315	0.034375	1.375	1.4025	1.237	1.559	2.022
22	0.028	0.025347	0.028	0.0286	0.0280	0.155	0.0295	0.03125	1.25	1.275	1.125	1.417	1.838
23	0.025	0.022571	0.024	0.0258	0.0250	0.153	0.027	0.028125	1.125	1.1475	1.012	1.256	1.654

24	0.022	0.0201	0.022	0.0230	0.0225	0.151	0.025	0.025	1	1.02	0.90	1.133	1.470
25	0.020	0.0179	0.020	0.0204	0.0200	0.148	0.023	0.021875	0.875	0.8925	0.7875	0.991	1.287
26	0.018	0.01594	0.018	0.0181	0.0180	0.146	0.0205	0.01875	0.75	0.765	0.675	0.850	1.102
27	0.016	0.014195	0.0164	0.0173	0.0170	0.143	0.01875	0.0171875	0.6875	0.70125	0.61875	0.779	1.001
28	0.014	0.012641	0.0148	0.0162	0.0160	0.139	0.0165	0.015625	0.625	0.6375	0.5625	0.708	0.919
29	0.013	0.011257	0.0136	0.0150	0.0150	0.134	0.0155	0.0140625	0.5625	0.57375	0.50625	0.637	0.826
30	0.012	0.010025	0.0124	0.0140	0.014	0.127	0.01375	0.0125	0.5	0.51	0.45	0.566	0.735
31	0.010	0.008928	0.0116	0.0132	0.0130	0.120	0.01225	0.0109375	0.4375	0.44625	0.39375	0.496	0.644
32	0.009	0.00795	0.0108	0.0128	0.0120	0.115	0.01125	0.01015625	0.40625	0.414375	0.3656	0.460	0.598
33	0.008	0.00708	0.0100	0.0118	0.0110	0.112	0.01025	0.009375	0.375	0.3825	0.3375	0.425	0.551
34	0.007	0.006304	0.0092	0.0104	0.0100	0.110	0.0095	0.00859375	0.34375	0.350625	0.309375	0.378	0.505
35	0.005	0.005614	0.0084	0.0095	0.0095	0.108	0.009	0.0078125	0.3125	0.31875	0.28125	0.354	0.459
36	0.004	0.005	0.0076	0.0090	0.0090	0.106	0.0075	0.00703125	0.28125	0.286875	0.253125	0.3185	0.413
37	.....	0.004453	0.0068	0.0085	0.0085	0.103	0.0065	0.006640625	0.265625	0.2709375	0.2391	0.302	0.390
38	.....	0.003965	0.0060	0.008	0.0080	0.101	0.00575	0.00625	0.25	0.255	0.225	0.2835	0.3675
39	.....	0.003531	0.0052	0.0075	0.0075	0.099	0.005						
40	.....	0.003144	0.0048	0.007	0.0070	0.097	0.0045						

[1] 07 means 0000000, 06 means 000000, etc.

[2] A variation of 2½ per cent may be expected either way. Iron assumed as 480 lb. per cubic foot, steel = 1.02 × iron, zinc = 0.9 × iron, copper = 1.133 × iron, and lead = 1.47 × iron.

10. Brass and Copper Pipe.

Table 122.—Weights and Dimensions of Seamless Drawn Brass and Copper Tubes

Iron pipe sizes	Iron pipe sizes[1]				Extra heavy				Plumbers' sizes				
	Inside diameter	Outside diameter	Approximate weight per lineal foot[3]		Inside diameter	Outside diameter	Approximate weight per lineal foot[2]		Size	Inside diameter	Outside diameter	Approximate weight per lineal foot	
			Brass	Copper			Brass	Copper				Brass	Copper
1/8	0.281	0.405	0.246	0.259	0.205	0.405	0.370	0.388					
1/4	0.375	0.540	0.437	0.461	0.294	0.540	0.625	0.650					
3/8	0.494	0.675	0.612	0.643	0.421	0.675	0.830	0.870	5/8	0.521	0.654	0.452	0.475
1/2	0.625	0.840	0.911	0.957	0.542	0.840	1.20	1.330	3/4	0.631	0.768	0.554	0.583
3/4	0.822	1.05	1.24	1.30	0.736	1.05	1.66	1.750	7/8	0.836	0.875	0.682	0.717
1	1.062	1.315	1.74	1.83	0.951	1.315	2.36	2.478	1	0.836	1	0.871	0.916
1¼	1.368	1.66	2.56	2.69	1.272	1.66	3.30	3.465	1¼	1.060	1.245	1.233	1.297
1½	1.600	1.90	3.04	3.20	1.494	1.90	4.25	4.462	1½	1.311	1.508	1.606	1.689
2	2.062	2.375	4.02	4.23	1.933	2.375	5.46	5.733	1¾	1.564	1.756	1.844	1.939
2½	2.500	2.875	5.83	6.14	2.315	2.875	8.30	8.715	2	1.815	2.007	2.123	2.232
3	3.062	3.50	8.31	8.75	2.892	3.50	11.20	11.760					
3½	3.500	4.00	10.85	11.41	3.358	4.00	13.70	14.385					
4	4.000	4.50	12.29	12.94	3.818	4.50	16.50	17.325					
4½	4.500	5.00	13.74	14.46									
5	5.062	5.563	15.40	16.21	4.813	5.563	22.80	23.940					
6	6.125	6.625	18.44	19.41	5.750	6.625	32.00	33.600					
7	7.062	7.625	23.92	25.17									
8	7.982	8.625	30.05	31.63									

Commercial lengths are 12 ft. long.

[1] Same as American Standard for iron pipe.

[2] These weights vary somewhat in practice.

[3] A. S. T. M. Standards. B43–23 and B42–23.

11. Brass Fittings.

TABLE 123.—DIMENSIONS OF THREADED BRASS FITTINGS
(Manufacturer's standard,[2] Crane Co., see Fig. 187b)

Size	1/8	1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4
A	9/16	11/16	3/4	15/16	1 1/8	1 5/16	1 9/16	1 3/4	2 3/16	2 9/16	3 1/16	3 7/16	3 3/4
B	1/2	9/16	5/8	11/16	13/16	15/16	1 1/8	1 1/4	1 7/16	1 11/16	2	2 3/8	2 1/2
C	...	.....	.....	.....	2 7/8	3 7/16	4 1/16	4 1/2	5 7/16	6 1/4			
D	...	.....	.....	.....	2	2 7/16	2 15/16	3 5/16	4 1/16	4 11/16			
E[1]	...	15/16	1 1/16	1 1/8	1 5/16	1 1/2	1 11/16	1 7/8	2 3/16	3 1/4	3 11/16		
F	7/16	9/16	5/8	11/16	3/4	7/8	1	1 1/8	1 5/16	1 1/2	1 3/4	1 7/8	2
G	7/8	15/16	1 1/16	1 1/8	1 5/16	1 1/2	1 11/16	1 7/8	2 3/16	2 9/16	3	3 1/8	3 3/8
H	1	1 1/8	1 1/4	1 7/16	1 5/8	1 7/8	2 3/16	2 7/16	2 7/8				

[1] For a reduction of one size only.
[2] Subject to slight variation and change.
Extra heavy brass fittings are obtainable with the same dimensions as cast-iron water fittings shown in Table 106.

TABLE 124.—DIMENSIONS OF BRASS FLANGED FITTINGS, 90-DEGREE ELBOWS, 45-DEGREE ELBOWS, TEES, AND CROSSES,
(Manufacturer's standard, Crane Co., see Fig. 180)

		1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2	5	6
Standard[1]	A	...	.....	.....	4 1/2	5	5 1/2	6	6 1/2	7	7 1/2	8
	C	...	.....	.....	2 1/2	3	3	3 1/2	4	4	4 1/2	5
	Flange thickness	...	.....	.....	1/2	9/16	5/8	11/16	11/16	23/32	3/4	13/16
Extra heavy[2]	A	4	4 1/4	4 1/2	5	5 1/2	6	6 1/2	7	7 1/2	8	8 1/2
	C	2	2 1/2	2 3/4	3	3 1/2	3 1/2	4	4 1/2	4 1/2	5	5 1/2
	Flange thickness	1/2	17/32	9/16	5/8	11/16	3/4	13/16	7/8	7/8	15/16	1

[1] Pressures up to 150 lb. per square inch.
[2] Pressures up to 250 lb. per square inch.

12. Standard Flanges.

TABLE 125.—TEMPLATES FOR DRILLING FLANGES
(American standard for cast iron, dimensions in inches)

Standard and low pressure							Medium and extra heavy						
Size	Diameter of flange	Thickness of flange	Bolt circle	Number of bolts	Size of bolts	Length of bolts	Size	Diameter of flange	Thickness of flange	Bolt circle	Number of bolts	Size of bolts	Length of bolts
1	4	7/16	3	4	7/16	1 1/2	1	4 1/2	11/16	3 1/4	4	1/2	2
1 1/4	4 1/2	1/2	3 3/8	4	7/16	1 1/2	1 1/4	5	3/4	3 3/4	4	1/2	2 1/4
1 1/2	5	9/16	3 7/8	4	1/2	1 3/4	1 1/2	6	13/16	4 1/2	4	5/8	2 1/2
2	6	5/8	4 3/4	4	5/8	2	2	6 1/2	7/8	5	4	5/8	2 1/2
2 1/2	7	11/16	5 1/2	4	5/8	2 1/4	2 1/2	7 1/2	1	5 7/8	4	3/4	3
3	7 1/2	3/4	6	4	5/8	2 1/4	3	8 1/4	1 1/8	6 5/8	8	3/4	3 1/4
3 1/2	8 1/2	13/16	7	4	5/8	2 1/2	3 1/2	9	1 3/16	7 1/4	8	3/4	3 1/4
4	9	15/16	7 1/2	8	5/8	2 3/4	4	10	1 1/4	7 7/8	8	3/4	3 1/2
4 1/2	9 1/4	15/16	7 3/4	8	3/4	2 3/4	4 1/2	10 1/2	1 5/16	8 1/2	8	3/4	3 1/2
5	10	15/16	8 1/2	8	3/4	2 3/4	5	11	1 3/8	9 1/4	8	3/4	3 3/4
6	11	1	9 1/2	8	3/4	3	6	12 1/2	1 7/16	10 5/8	12	3/4	3 3/4
7	12 1/2	1 1/16	10 3/4	8	3/4	3	7	14	1 1/2	11 7/8	12	7/8	4
8	13 1/2	1 1/8	11 3/4	8	3/4	3 1/4	8	15	1 5/8	13	12	7/8	4 1/4
9	15	1 1/8	13 1/4	12	3/4	3 1/4	9	16 1/4	1 3/4	14	12	1	4 3/4
10	16	1 3/16	14 1/4	12	7/8	3 1/2	10	17 1/2	1 7/8	15 1/4	16	1	5
12	19	1 1/4	17	12	7/8	3 1/2	12	20 1/2	2	17 3/4	16	1 1/8	5 1/4

Bolt holes are drilled 1/8 in. larger than nominal diameter of bolts.

TABLE 126.—TEMPLATES FOR DRILLING BRASS FLANGES
(Manufacturer's standard, dimensions in inches)

Heavy, for pressures up to 150 lb. per square inch							Extra heavy, for pressures up to 250 lb. per square inch						
Size	Diameter of flange	Thickness of flange	Bolt circle	Number of bolts	Size of bolts	Length of bolts	Size	Diameter of flange	Thickness of flange	Bolt circle	Number of bolts	Size of bolts	Length of bolts
1/4	2 1/2	9/32	1 11/16	4	3/8	1	1/4	3	3/8	2	4	7/16	1 1/4
3/8	2 1/2	9/32	1 11/16	4	3/8	1	3/8	3	3/8	2	4	7/16	1 1/4
1/2	3	5/16	2 1/8	4	3/8	1 1/4	1/2	3 1/2	13/32	2 3/8	4	7/16	1 1/2
3/4	3 1/2	11/32	2 1/2	4	3/8	1 1/4	3/4	4	7/16	2 7/8	4	1/2	1 1/2
1	4	3/8	3	4	7/16	1 1/4	1	4 1/2	1/2	3 1/4	4	1/2	1 3/4
1 1/4	4 1/2	13/32	3 3/8	4	7/16	1 1/2	1 1/4	5	11/32	3 3/4	4	1/2	1 3/4
1 1/2	5	7/16	3 7/8	4	1/2	1 1/2	1 1/2	6	9/16	4 1/2	4	5/8	2
2	6	1/2	4 3/4	4	5/8	1 3/4	2	6 1/2	5/8	5	4	5/8	2
2 1/2	7	9/16	5 1/2	4	5/8	2	2 1/2	7 1/2	11/16	5 7/8	4	3/4	2 1/4
3	7 1/2	5/8	6	4	5/8	2	3	8 1/4	3/4	6 5/8	8	3/4	2 1/2
3 1/2	8 1/2	11/16	7	8	5/8	2 1/4	3 1/2	9	13/16	7 1/4	8	3/4	2 3/4
4	9	11/16	7 1/2	8	5/8	2 1/4	4	10	7/8	7 7/8	8	3/4	2 3/4
4 1/2	9 1/4	23/32	7 3/4	8	3/4	2 1/2	4 1/2	10 1/2	7/8	8 1/2	8	3/4	2 3/4
5	10	3/4	8 1/2	8	3/4	2 1/2	5	11	15/16	9 1/4	8	3/4	3
6	11	13/16	9 1/2	8	3/4	2 3/4	6	12 1/2	1	10 5/8	12	3/4	3
7	12 1/2	7/8	10 3/4	8	3/4	2 3/4	7	14	1 1/16	11 7/8	12	7/8	3 1/4
8	13 1/2	15/16	11 3/4	8	3/4	3	8	15	1 1/8	13	12	7/8	3 1/2
9	15	15/16	13 1/4	12	3/4	3	9	16 1/4	1 1/8	14	12	1	3 1/2
10	16	1	14 1/4	12	7/8	3 1/4	10	17 1/2	1 3/16	15 1/4	16	1	3 3/4
12	19	1 1/16	17	12	7/8	3 1/4	12	20 1/2	1 1/4	17 3/4	16	1 1/8	4

13. Lead Pipe and Sheet Lead.

TABLE 127.—WEIGHT, THICKNESS, AND WORKING STRENGTH OF LEAD PIPE

Trade name		Internal diameter in inches													
		3/8	1/2	5/8	3/4	7/8	1	1 1/4	1 1/2	1 3/4	2	2 1/2	3	3 1/2	4
Aqueduct	Weight[1]	1/2	5/8	3/4	1	1 1/2	1 1/2	2	3	3	3	4	4	.....	5
	Thickness[2]	0.072	0.072	0.070	0.077	0.098	0.089	0.095	0.118	0.102	0.092	0.100	0.082	.....	0.080
	Pressure[3]	75	60	45	40	45	35	30	30	25	20	15	10	.....	8
Extra light	Weight	9/16	3/4	1 1/4	1 1/2	2	2	2 1/2	3 1/2	3 3/4	4	.....	4 3/4	5	6
	Thickness	0.078	0.082	0.110	0.112	0.127	0.115	0.118	0.135	0.127	0.123	.....	0.100	0.088	0.090
	Pressure	80	65	70	60	60	45	40	35	30	25	.....	15	10	9
Light	Weight	3/4	1	1 3/4	2	2 1/2	2 1/2	3	4	4 1/2	5	6	6 3/16	.....	8
	Thickness	0.102	0.106	0.147	0.144	0.155	0.141	0.138	0.153	0.153	0.150	0.147	0.130	.....	0.12
	Pressure	110	85	95	75	70	55	45	40	35	30	25	15	.....	10
Medium	Weight	1	1 1/4	2	2 1/4	3	3 1/4	3 3/4	5	5 1/2	7	8	9	.....	10
	Thickness	0.129	0.128	0.164	0.160	0.182	0.207	0.171	0.187	0.185	0.204	0.190	0.182	.....	0.155
	Pressure	140	100	105	85	85	85	55	50	40	40	30	25	.....	15
Strong	Weight	1 1/2	1 3/4	2 1/2	3	3 1/2	4	4 3/4	6	6 1/2	8	11	13	15	16
	Thickness	0.176	0.169	0.196	0.201	0.207	0.212	0.209	0.221	0.213	0.231	0.259	0.230	0.254	0.240
	Pressure	190	135	125	105	95	85	65	60	50	45	40	30	30	25
Extra strong	Weight	2	2 1/2	3	3 1/2	.....	4 3/4	6	7 1/2	8	9	14	16	18	21
	Thickness	0.218	0.223	0.227	0.230	.....	0.246	0.255	0.270	0.256	0.259	0.320	0.311	0.300	0.315
	Pressure	232	180	145	125	.....	100	80	70	60	50	50	10	35	30
Double extra strong	Weight	2 5/8	3	3 1/2	4	.....	5 1/2	6 3/4	9	.....	10 1/2	17	20	.....	25
	Thickness	0.265	0.254	0.256	0.259	.....	0.277	0.284	0.317	.....	0.297	0.380	0.382	.....	0.370
	Pressure	280	200	164	140	.....	110	90	85	.....	60	60	50	.....	35

[1] Pounds per foot length of pipe.
[2] Thickness of wall in inches.
[3] Computed working pressure, internal, pounds per square inch = one-tenth bursting pressure on basis of breaking tensile strength of lead = 2,000 lb. per square inch.

For weights and dimensions of lead traps see Table 53.

For weights of sheet lead see Table 121.

Lead soil, waste, and vent pipes or flush pipes, including bends and traps should be of the weights classed as "light" in Table 127. Lead water-supply pipe above ground should be "strong" and lead water-supply pipe below ground should be "extra strong." Sheet lead should weigh not less than 4 lb. per square foot except for lead safe pans which should weigh at least 6 lb. per square foot.

14. Vitrified Clay Pipe.

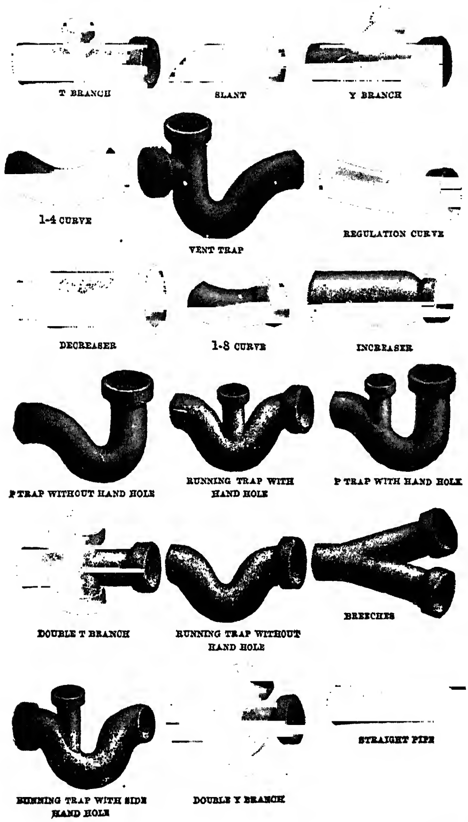


Fig. 188.—Vitrified clay pipe and specials. (*Courtesy of Blackmer and Post, Pipe Manufacturing Company.*)

Table 128.—Properties of Clay Sewer Pipe

(Abstracts from tentative specifications of the American Society for Testing Materials)

Internal diameter, inches	Depth of socket, inches	Thickness of barrel, inches	Minimum crushing strength pounds per linear foot*	Internal diameter, inches	Depth of socket, inches	Thickness of barrel, inches	Minimum crushing strength pounds per linear foot*
6	2	5/8	1,430	21	3	1 3/4	2,590
8	2 1/4	3/4	1,430	24	3	2	3,070
10	2 1/2	7/8	1,570	27	3 1/2	2 1/4	3,370
12	2 1/2	1	1,710	30	3 1/2	2 1/2	3,690
15	2 1/2	14	1,960	33	4	2 5/8	3,930
18	3	1 1/2	2,200	36	4	2 3/4	4,400

Laying lengths are 2 ft., 2 1/2 ft., and 3 ft. Taper of socket is 1:20.

* Concentrated load at end of vertical diameter.

Table 129.—Dimensions of Deep and Wide Sockets. Vitrified-clay Pipe

(Standard or double strength manufacturer's standard)

Internal diameter, inches	Depth of socket, inches	Annular space, inches	Internal diameter, inches	Depth of socket, inches	Annular space, inches
4	2	1/2	15	3	5/8
6	2 1/2	5/8	18	3 1/4	5/8
8	2 3/4	5/8	21	3 5/8	5/8
10	2 3/4	5/8	24	4	5/8
12	3	5/8			

15. Solder Metals.—The following specifications for solder metals are abstracted from "Standard Specifications for Solder Metal," Serial designation B32–21, of the American Society for Testing Materials:

Chemical Properties and Tests

4. The alloys shall conform to the following requirements as to chemical composition, within the limits specified in Sec. 5.

Class A					Class B				
Grade No.	Per cent of				Grade No.	Per cent of			
	Tin	Lead	Antimony	Copper		Tin	Lead	Antimony	Copper
0	63.00	37.00	0.12	0.08	1	49.25	50.00	0.75	0.15
1	50.00	50.00	0.12	0.08	2	43.50	55.00	1.50	0.15
2	45.00	55.00	0.12	0.08	3	38.00	60.00	2.00	0.15
3	40.00	60.00	0.12	0.08	4	35.50	62.50	2.00	0.15
4	37.50	62.50	0.12	0.08	5	31.00	67.00	2.00	0.15
5	33.00	67.00	0.12	0.08					

Other impurities, exclusive of bismuth, limited to 0.10 per cent.

No zinc or aluminum permitted.

5. The permissible variation plus or minus in the percentage of tin shall not be over 1 per cent of the tin contents specified in Sec. 4.

Appendix.—It is recommended that the grade of solder metal be selected which contains the least amount of tin required to give suitable flowing and adhesive qualities for the work in hand.

TABLE SHOWING MELTING POINTS OF SOLDER METAL

Grade	Per cent			Melting point		Complete liquidation point	
	Tin	Lead	Antimony	Centigrade	Fahrenheit	Centigrade	Fahrenheit
Tin	100.00	......	....	232	449.6	232	449.6
0A	63.00	37.00	0.12	181	357.8	181	357.8
1A	50.00	50.00	0.12	181	357.8	213	415.4
1B	49.25	50.00	0.75	185	365.0	208	397.4
2A	45.00	55.00	0.12	181	357.8	225	437.0
2B	43.50	55.00	1.50	188	370.4	220	428.0
3A	40.00	60.00	0.12	181	357.8	237	458.6
3B	38.00	60.00	2.00	188	370.4	228	442.4
4A	37.50	62.50	0.12	181	357.8	241	467.6
4B	35.50	62.50	2.00	188	370.4	231	411.8
5A	33.00	67.00	0.12	181	357.8	252	485.6
5B	31.00	67.00	2.00	188	370.4	235	455.0
Lead	......	100.00	....	327	620.6	327	620.6

Note.—See also Table 73.

16. Hot-water Storage and Expansion Tanks and Heating Coils.

TABLE 130.—DIMENSIONS OF RANGE BOILERS[3]

Size, inches		Capacity, gallons	Size, inches		Capacity, gallons	Size, inches		Capacity, gallons
Diameter[1]	Length[2]		Diameter[1]	Length[2]		Diameter[1]	Length[2]	
12	36	18	16	48	42	22	60	100
12	48	24	16	60	52	24	60	120
12	60	30	18	60	66	24	72	144
14	48	32	20	60	82	24	96	192
14	60	40						

[1] Diameters refer to inside measurements.
[2] Length means length of sheet, not over-all length of boilers.
[3] Recommendation Number 8, approved May 1, 1924, by the Division of Simplified Practice, U. S. Dept. of Commerce.

TABLE 131.—DIMENSIONS OF EXPANSION TANKS[1]

Size, inches		Capacity, gallons	Size, inches		Capacity, gallons	Size, inches		Capacity, gallons
Diameter	Length		Diameter	Length		Diameter	Length	
12	20	10	14	30	20	16	36	32
12	30	15	16	30	26	16	48	42

[1] Recommendation Number 8, approved May 1, 1924, by the Division of Simplified Practice, U. S. Dept. of Commerce.

TABLE 132.—STANDARD DIMENSIONS OF HOT-WATER[1] STORAGE TANKS

Diameter, inches, inside	Length of sheet, feet	Capacity, gallons	Heating coil size, inches	Minimum length heating coil, feet
20	5	82	1	14
24	5	118	1¼	14
24	6	141	1¼	18
30	6	220	1¼	18
30	8	294	1¼	26
36	6	318	1½	18
36	8	423	1½	26
42	7	504	1½	26
42	8	576	1½	26
42	10	720	1½	34
42	14	1,008	1½	50
48	10	940	2	34
48	16	1,508	2	58
48	20	1,880	2	74

[1] Recommendation No. 25 Simplified Practice Division, U. S. Department of Commerce, 1925.

TABLE 133.—WEIGHTS AND CAPACITIES OF HOT WATER STORAGE TANKS[1]

Galvanized and cold welded		Weights in pounds					Galvanized and cold welded		Weights in pounds					Copper: Standard for 100 lb. per square inch; Heavy for 150 lb. per square inch	
		Galvanized		Cold welded					Galvanized		Cold welded				
Capacity, gallons	Dimensions, inches	Standard 150 lb. per square inch	Extra heavy 200 lb. per square inch	Standard 150 lb. per square inch	Extra heavy 200 lb. per square inch	Double extra heavy 250 lb. per square inch	Capacity, gallons	Dimensions, inches	Standard 150 lb. per square inch	Extra heavy 200 lb. per square inch	Standard 150 lb. per square inch	Extra heavy 200 lb. per square inch	Double extra heavy 250 lb. per square inch	Capacity, gallons	Dimensions, inches
18	12 by 36[2]	50	...	53	...	...	48	14 by 72	106	...	...	...	...	30	12 by 60
21	12 by 42	58	...	62	...	...	52	16 by 60[2]	117	139	121	138	167	35	13 by 60
24	12 by 48[2]	60	72	65	81	109	53	18 by 48	124	...	130	...	...	40	14 by 60
24	14 by 36	61	67	66	83	...	63	16 by 72	140	166	...	...	...	50	16 by 60
27	12 by 54	68	84	72	90	...	66	18 by 60[2]	147	165	154	172	...	60	18 by 60
28	14 by 42	71	...	75	...	...	79	18 by 72	171	...	...	...	...	80	20 by 60
30	12 by 60[2]	73	87	79	94	127	82	20 by 60[2]	174	202	...	...	...	100	22 by 60
32	14 by 48[2]	75	...	82	...	...	98	20 by 72	199	...	...	...	...	120	24 by 65½
35	13 by 60	82	98	86	102	135	100	22 by 60[2]	202	229	...	...	...	125	24 by 69
36	12 by 72	89	...	...	...	...	120	24 by 60[2]	260	...	...	...	...	150	24 by 78½
36	14 by 54	84	...	89	...	...	141	24 by 72[2]	294	...	...	...	...	200	26 by 87
40	14 by 60[2]	89	105	92	110	144	168	24 by 84	325						
42	16 by 48[2]	98	115	102	120	...	192	24 by 96[2]	375						
47	16 by 54	110	...	114											

[1] Simplified Practice Recommendation No. 25, U. S. Department of Commerce, Dec. 31, 1924.
[2] Simplified Practice Recommendation No. 8, for Range Boilers. U. S. Department of Commerce, 1924.

"In accordance with the unanimous action of the joint conference of representatives of manufacturers, distributors, and users or range boilers and expansion tanks, held on Oct. 30, 1923, the U. S. Department of Commerce, through the Bureau of Standards, recommends that the recognized sizes of range boilers and expansion tanks be reduced to those shown in Table 130.

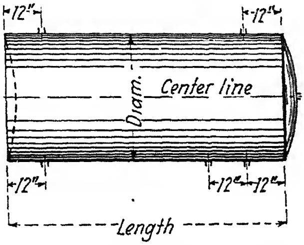


FIG. 189.—Standard location of openings for hot-water storage tanks. Recommendation No. 25, approved Dec. 31, 1924 by the Division of Simplified Practice, U. S. Department of Commerce.

"It is further recommended that:

I. Range boilers have one side tapping 6 in. from the top and one 6 in. from the bottom (measurements to be made from the edge of the shell plate), and two tappings in the top and one in the bottom. All tappings to be 1 in.; ½-in. top and the ¾-in. side and bottom tappings on vertical boilers to be eliminated (see Fig. 190A).

II. The "short size" boiler (that is, 12 by 58 in.) now used in New York, N. Y., be eliminated.

III. Five 1-in. openings to be considered as standard for horizontal boilers.

IV. The 16- by 48-in. boiler be advertised as of its actual capacity (*viz.*, 42 gal.) in lieu of No. 18, to avoid confusion with present 18-gal. boiler.

V. All range boilers and combination boiler and gas water heaters be rated by their actual water capacity in gallons.

'In accordance with the unanimous action on Mar. 13 and May 13, 1924, of two general conferences of representatives of manufacturers, and users of hot-water storage tanks, the U. S. Department of Commerce, through the Bureau of Standards, recommends that simplified dimensions and capacities of hot-water storage tanks be established as shown in Table 132.

(*a*) These sizes to be made in two working pressures, *viz.*, 65 lb. per square inch, and 100 lb. per square inch.

(*b*) Those made for 65 lb. working pressure are to be classified as '*standard*,' and those for 100 lb. working pressure as '*Extra Heavy*.'

(*c*) Each tank is to be stenciled with its proper classification, working pressure, also the name and address of its manufacturer, as follows:

1. *Standard.*—Guaranteed for 65 lb. working pressure.
   Manufacturer's name and address, or
2. *Extra Heavy.*—Guaranteed for 100 lb. working pressure.
   Manufacturer's name and address.

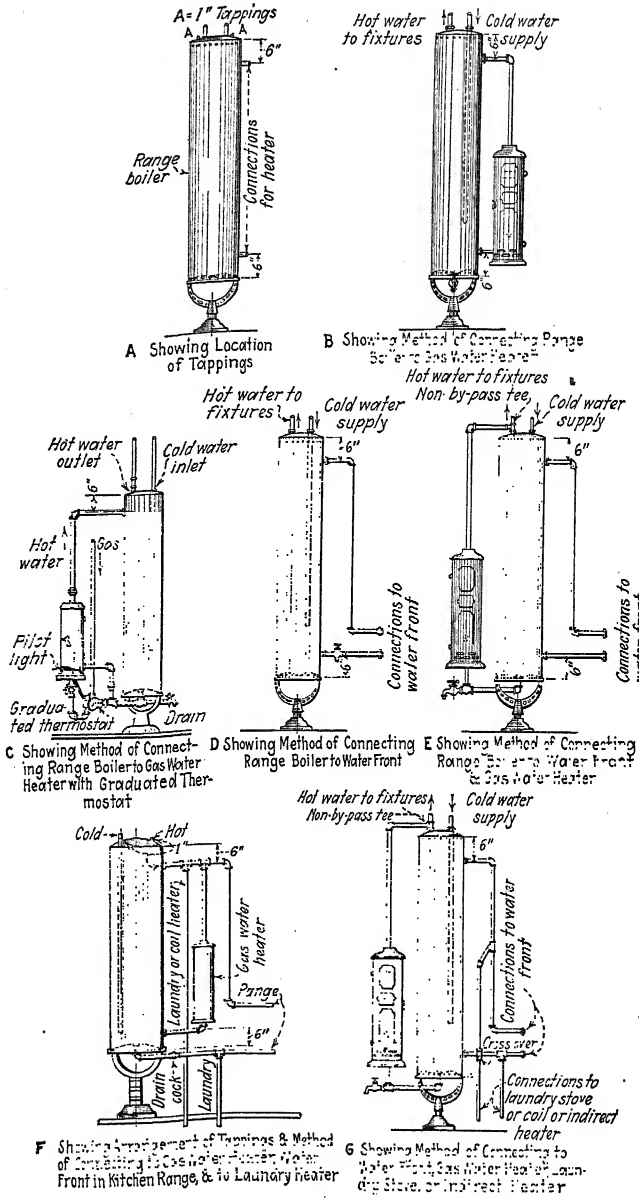


FIG. 190.—Standard range boiler connections. (Division of Simplified Practice U. S. Department of Commerce.)

3. *Factors of Safety, Thicknesses, etc.*—These are to be in accord with the A. S. M. E. code for 'Non-fired pressure vessels.'

4. *Interchangeability.*—The tanks above listed are to be made interchangeable for either horizontal or vertical installation.

5. *Tappings.*—There are to be six tappings in each tank, placed as follows:*

One in center of convex head. Two in the shell, in line (parallel with axis of tank), each to be centered 12 in. from the edge of the sheet. Three in the shell, in line, said line to be diametrically opposite from the line of the two just mentioned. Of these three, one is to be centered 12 in. in from the convex end; another 24 in. in from that end; and the third is to be centered 12 in. in from the concave end. All measurements are taken from the edge of the sheet. There is no tapping in the concave, or bottom, end. All tappings in tanks up to but not including 30 in. in diameter are to be 1½ in.; from 30 in. up to but not including 48 in. are to be 2 in.; and from 48 in. upward, the tappings are to be 3 in. All threads are to be American Standard taper pipe threads. These tappings apply to either horizontal or vertical installations.

6. *Manholes.*—These are to be standard size, 11 by 15 in., and may be placed either in the shell or in the head.

7. *Handholes.*—These are to be 4 by 6 in. located as desired.

8. *Heating Coils.*—Coils for either horizontal or vertical installation of these tanks must not be less in size or total length than appears in Table 132."

17. Vitreous Ware.—The following recommendations concerning vitreous china plumbing fixtures were made effective Oct. 1, 1926, by the Division of Simplified Practice of the U. S. Department of Commerce:

Simplified Practice Recommendation No. 52, on Vitreous China Plumbing Fixtures

In accordance with the unanimous action on Sept. 25, 1926, of a general conference of representatives of manufacturers, distributers, and users, the Department of Commerce, through the Bureau of Standards recommends the establishment of the following standards for staple vitreous china plumbing fixtures.

General

1. The nomenclature, definitions, grading rules, sizes, dimensions and general practices given herein are recommended as standard.

2. Types and sizes of water-closet bowls, tanks and lavatories not specifically mentioned shall be considered as special.

3. Catalogues displaying vitreous china plumbing fixtures should, as near as possible, conform to recommended standard items and where specials are exhibited they should be so indicated.

Grading Rules

4. Vitreous china plumbing fixtures shall be graded in accordance with the grading rules given herein.

5. Vitreous china plumbing fixtures are made of materials mined from the earth, containing metallic elements and foreign matter which cannot be entirely eliminated in practice. As they are made and finished by hand,

*See Fig. 189.

and subjected to a high degree of heat, it is an accepted fact that they cannot be regularly free from unimportant variations and minor blemishes.

6. Careful inspection is employed in each department of manufacture and each of the imperfections listed herein as acceptable under the "Regular Selection" grading is caused by some unavoidable condition in the manufacturing process. Perfection is not guaranteed nor commercially possible.

7. The blemishes permitted under the grading rules do not affect the utility or value of the fixture.

8. The terms "regular selection" and "culls" shall be used to replace the terms "Grade A" and "Grade B" for grading vitreous china plumbing fixtures, as it is recognized that the terms "Grade A" and "Grade B" are confusing to the trade and to the consumer.

9. Ware which grades below "regular selection" shall be classified as "culls."

Nomenclature and Definitions

Blister.—A raised uncolored portion of the surface, 1/32 (0.031) in. and less than 1/8 (0.125) in. in maximum dimension.

Large Blister.—A raised uncolored portion of the surface 1/8 (0.125) in. to 1/4 (0.25) in. inclusive in maximum dimension.

Bubble.—An uncolored raised portion of the surface or a sand speck smaller than 1/32 (0.031) in. in maximum dimension.

Craze.—Fine cracks in the glaze.

Culls.—Ware which grades below "regular selection."

Discoloration.—A colored spot over 1/4 (0.25) in. in maximum dimension, or a sufficient number of specks or spots to give the effect of a change in color.

Dull or Eggshell Finish.—Dead or flat finish. Undeveloped glaze. A semi-glazed finish with numerous very fine pin holes or slightly matted in appearance. Not glossy.

Dunt.—A hair-line fracture extending through the body and due to strains set up in the process of manufacture.

Exposed Body.—Unglazed portion 1/16 (0.063) in. in maximum dimension or over.

Finish.—Texture and condition of surface other than color.

Fire Check.—Fine, shallow crack in the body not covered with glaze. When sufficiently covered with glaze as to be easily cleaned it is not detrimental.

Flushing Surface.—The surface which may be wet during the operation of the fixture.

Pin Hole.—Unglazed portion of body, or small hole under 1/16 (0.063) in. in maximum dimension.

Polishing Mark.—A spot not larger than 3/8 (0.375) in. in maximum dimension where some minor blemish has been ground off and the surface polished.

Pottery Square.—A square 2 in. on each side. For grading purpose may be a 2-in. sq. hole cut in a small sheet of any flexible material—such as rubber or paper—for convenience in sliding over irregular surfaces to determine segregation.

Projection.—A raised uncolored portion of the surface over ¼ (0.25) in. in maximum dimension.

Regular Selection.—First-class ware in conformity with the limitation of the grading rules.

Roughing-in Measurement.—Dimensions from finished wall or floor to center of waste or supply opening.

Segregation.—More than four spots, blisters, or pin holes in any "pottery square."

Speck.—A colored portion less than $\frac{1}{32}$ (0.031) in. in maximum dimension. Specks less than $\frac{1}{100}$ (0.01) in. in maximum dimension, unless in sufficient number to form a discoloration, are not counted.

Spot.—A colored portion of the surface $\frac{1}{32}$ (0.031) in. and less than ⅛ (0.125) in. in maximum dimension.

Large Spot.—A colored portion ⅛ (0.125) in. to ¼ (0.25) in. inclusive, in maximum dimension.

Spud.—Threaded brass connection inserted in the vitreous china ware.

Streak.—A slight defect in the finish giving the appearance similar to painters' brush marks.

Visible Surface.—The surface readily visible after installation of the fixture by an observer in normal standing position.

Vitreous China Plumbing Fixtures.—The term "vitreous china" shall be applied only to such plumbing fixtures as will pass the following red ink test: A fractured piece of material taken from any part of a vitreous china plumbing fixture, after being immersed in red anilin ink of good color strength for one hour, shall not show any discoloration through the glaze and shall not show absorbtion when broken, to a depth greater than ⅛ in. below the surface of fracture at any point.

Water-closet Bowl.—The term "water-closet bowl" is the accepted general term applicable to such fixtures.

Reverse Trap.—The term "reverse trap" shall be applied only to water-closet bowls having back supply; integral flushing rim; a minimum water seal of 2½ in.; a minimum water area of 8¾ by 7½ in.; a siphon trapway at the rear of closet which shall pass a 1½ in. diameter solid ball; and a minimum weight of 38 lb.

Reverse Trap, with Jet.—Same as reverse trap, with jet added.

Siphon Jet.—The term "siphon jet" shall be applied only to water-closet bowls having top supply, integral flushing rim and jet; a minimum water area of 10 by 12 in.; a minimum depth of seal of 3 in.; a siphon trapway which shall pass a 2⅛-in. diameter solid ball; minimum horizontal overall dimensions of 14 by 23 in.; and a minimum weight of 48 lb.

Washdown.—The term "washdown" shall be applied only to water-closet bowls having back supply; integral flushing rim; a minimum water area of 8 by 7 in.; a minimum water seal of 2½ in.; a siphon trapway at the front of the closet which shall pass a 1½ in. solid ball; and a minimum weight of 34 lb.

Washdown, with Jet.—Same as washdown, with jet added.

Water Area.—Elliptical area of the still water in the water-closet bowl, when filled to the top of the dam.

Wavy Finish.—A defect in the finish having the appearance of numerous runs in the glaze; irregular or mottled.

Method of Grading Water-closet Bowls

10. Examine the well hole closely for excess glaze, spots, blisters, pin holes, etc. With eyes 2 ft. directly above rim, rock the bowl first to one side and then the other to an angle of about 45 deg., then tilt backward at the same angle, noting only the defects which can be observed in these positions. Minor blemishes which cannot be observed in this operation are assumed to be on unseen surfaces. Examine the remainder of the bowl for dunts, craze or other serious defects.

Note.—It is not intended that inspectors shall measure or count any blemishes except in case of doubt, since with practice, dimensional limits and numbers can be readily gaged by eye.

11. Water-closet bowls are graded in accordance with the maximum blemishes listed. See Table 134.

12. Bowls having more than the maximum grading limit permissible for "regular selection" on any one blemish shall be classified as "culls."

Table 134.—Water-closet Bowls

Location	Blemish or defect	Regular selection
General	Dull or eggshell area	Not over 4 sq. in.
	Wavy finish	Not more than 4 sq. in.
	Excess glaze	Not more than ⅛ in. thick in well
	Warpage	Not noticeably warped when seat is attached
	Large blisters	Not more than two
	Dunts	None allowed
	Projections	None allowed
Flushing surface	Exposed body	None allowed
	Unglazed fire check	None allowed
	Spots, blisters, or pin holes	No segregation; a total of not over ten
	Bubbles or specks	Not over ten, in one "pottery square;" a total of not over 25
Visible surface	Exposed body	Not over ¼ (0.25) in. on foot; not over ⅛ (0.125) in. on more prominent surfaces
	Unglazed fire check	Not over ½ in. long
	Spots, blisters, or pin holes	No segregation; total not over ten
	Bubbles or specks	Not over five in one "pottery square;" a total of not over 25

Method of Grading Low Tanks and Covers

13. Low tanks are installed at a level where blemishes are more readily visible than on water-closet bowls and although less likely to become soiled,

are graded about as closely for appearance. Tanks and covers are graded separately on an equal basis for segregation of blemishes. The covers shall be limited to about one-half the total blemishes permitted for tanks. No blemishes on the inside surface are counted. Minor blemishes on the outside surface, hidden by the cover, are not counted. Examination should be made with the eyes of the observer about 2 ft. from the surface observed.

14. Low tanks are graded in accordance with the blemishes listed. See Table 135.

15. Low tanks having more than the maximum grading limit permissible for "regular selection" on any one blemish shall be classified as "culls."

TABLE 135.—LOW TANKS

Location	Blemish or defect	Regular selection
General	Warpage	Not noticeably warped
	Dunts	None allowed
Visible surface	Dull or eggshell area	Not over 2 sq. in.
	Wavy finish	Not more than 4 sq. in.
	Exposed body	Not over 1/8 (0.125) in.
	Unglazed fire check	Not over 1/4 in. long
	Spots, blisters, or pin holes	No segregation; a total of not over 10
	Bubbles or specks	Not over 5 in one "pottery square;" a total of not over 25

Note.—Covers showing more than 50 per cent of the allowable number of blemishes listed for low tanks shall be classified as "culls."

METHOD OF GRADING VITREOUS CHINA LAVATORIES, PEDESTALS AND LEGS

16. Since lavatories are installed at a level where blemishes are more readily noticeable than on water-closet bowls and tanks, they should be graded more closely than any other vitreous china fixture.

17. Lavatories should be examined with the eyes of the observer about 2 ft. from the surface observed.

18. The top of slab, front apron, inside of bowl, and face of back of lavatories with back, are most important. Sides should not be subjected to the same rigid inspection.

19. Warpage tests are made at factory by use of horizontal plane, this being a level table upon which lavatory is allowed to rest, face down, and tested with thickness gages placed between lavatory and table.

20. Pedestals and legs are graded the same as water-closet bowls.

21. Pedestals and legs are not to be warped out of perpendicular line more than 1/2 in. To be free from rough projections. No exposed body over 1/2 in.

22. Vitreous china lavatories are graded in accordance with the maximum blemishes listed in Table 136. Any vitreous china lavatory having more

than the maximum grading limit permissible for "regular selection" on any one blemish shall be classified as a "cull."

TABLE 136.—VITREOUS CHINA LAVATORIES

Location	Blemish or defect	Regular selection
General	Dunts	None allowed
	Crazing	None allowed
		On 24 by 20-in. lavatories and larger, warpage of slab out of horizontal plane not to exceed ⅜ in. On smaller than 24-in. lavatories warpage of slab out of horizontal plane not to exceed ¼ in.
		The same deviation to apply on lavatories with back, when attached to wall.
Service space, top of slab, inside of bowl and front of apron	Dull or eggshell	One allowed; not over ½ in
	Exposed body	None allowed
	Unglazed fire check	None allowed
	Spots, blisters and pin holes	No segregation; a total of not more than eight
	Bubbles or specks	Not more than three in one "pottery square" a total of not more than eight
	Polishing mark	No segregation; not more than two allowed
Face of integral back and sides	Dull or eggshell	One allowed; not over ½ in.
	Exposed body	None over ½ in.; not more than two allowed
	Large blisters	Not more than two on either side or back; a total of not more than six
	Unglazed fire check	None on back, not more than one on either side
	Spots, blisters, and pin holes	No segregation; not more than five on either side or back. A total of not more than 15
	Bubbles or specks	Not more than four in one "pottery square;" a total of not more than 12

GRADING RULES FOR OTHER VITREOUS CHINA PLUMBING FIXTURES

23. The grading rules for water-closet bowls shall apply to slop sinks, clinic sinks, and bidets.

24. The grading rules for, and method of grading, lavatories, pedestals and legs shall apply to drinking fountains, manicure tables, and toilet tables.

25. All vitreous china plumbing fixtures not specifically mentioned in the foregoing shall take the grading rules for, and method of grading, water-closet bowls.

MARKING AND LABELING

26. Water-closet bowls, tanks, tank covers, lavatories, and all other vitreous china plumbing fixtures shall bear the trade-mark or name of the

actual manufacturer and the words "Made in U. S. A.," applied in such manner as to be permanent and visible after installation. It is recommended that no name, brand, or label other than that of the manufacturer be used on the ware.

27. "Regular selection" labels shall be used only on such ware as conforms to the requirements for "regular selection," as set forth in the grading rules. No label shall be used on ware which grades below "regular selection." Labels shall be applied only at the factory.

28. The following labels shall be used on labels for "regular selection" ware:

"This is a high-class and valuable piece of vitreous china and should be handled as such. This piece has been classified as 'regular selection' after a thorough inspection by competent and experienced men. The term 'regular selection' does not mean that this article is without blemish. It is impossible to make vitreous china plumbing fixtures without flaws of some kind and these have not been overlooked in the grading of this article. This piece has been graded in accordance with uniform grading rules adopted by the Sanitary Potteries in conjunction with the U. S. Bureau of Standards of the Department of Commerce."

29. Culls shall be marked by the maker with two parallel lines cut through the glaze into the body of the ware at the location recommended by the Manufacturers' Advisory Committee on Vitreous China Plumbing Fixtures. These cuts shall be filled with a bright red varnish or enamel which is resistant to the action of hot water.

30. All crates containing culls shall be marked with two splashes of red on end of the crate so as to be visible without tearing down stacks.

Dimensional Standards

31. The standard size of spuds on all water-closet bowls shall be as follows: 2 in. for all closet bowls operated under low-down tanks; 1½ in. for all other installations.

32. Soap-dish depressions shall be used on all lavatories, to and including the 24-in. size, but not on larger sizes.

33. Wherever soap-dish depressions are used on slabs of lavatories, they shall be located on the left-hand side as one faces the lavatory, and shall be approximately 3¼ in. long, by 2¼ in. wide, by ⅛ in. deep at the deepest point, and shall drain into bowl.

34. When not otherwise specified, a variation of 5 per cent from the dimensions indicated herein will be permitted.

35. Underlined dimensions are identical for all sizes and types of similar items.

36. The total thickness of lavatories at faucet or valve holes shall not be less than ½ in., nor more than 1¼ in.

37. The total thickness of lavatories at waste outlets shall be not less than 1¼ in., nor more than 1⅞ in.

38. Supply pipes to floor for standard washdown combinations are furnished 19 in. long.

For roughing-in dimensions see Figs. 191 to 196.

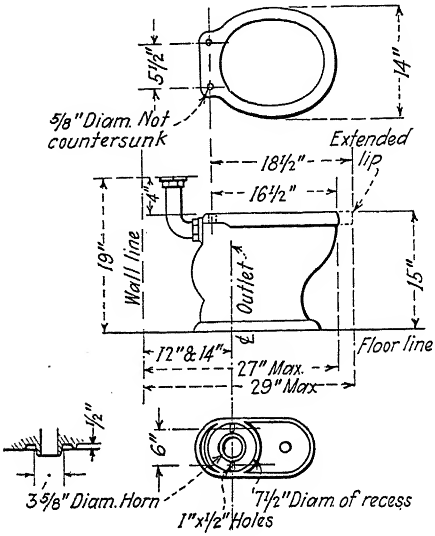


FIG. 191.—Standard dimensions, reverse trap water-closet bowls. (*Division of Simplified Practice.*)

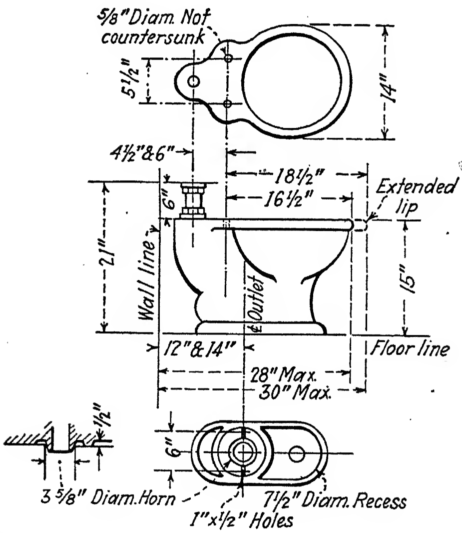


FIG. 192.—Standard dimensions, siphon jet water-closet bowls. (*Division of Simplified Practice.*)

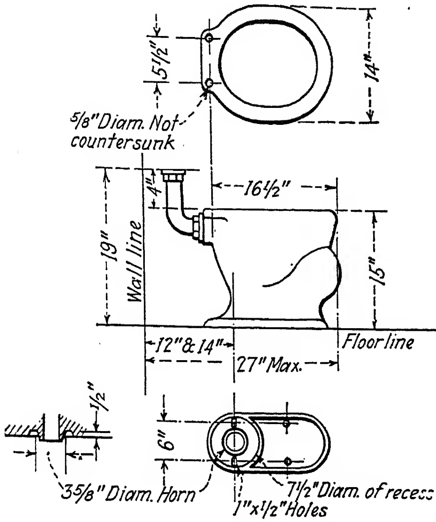


FIG. 193.—Standard dimensions, wash down water-closet bowls. (*Division of Simplified Practice.*)

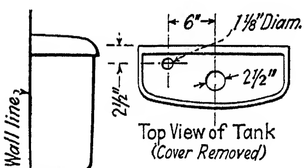


FIG. 194.—Standard dimensions of low-down tanks. (*Division of Simplified Practice.*)

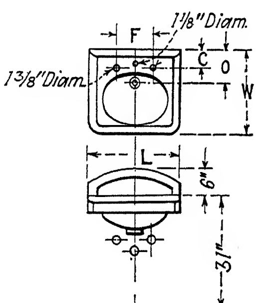


FIG. 195.—Standard dimensions of wall lavatories. (*Division of Simplified Practice.*)

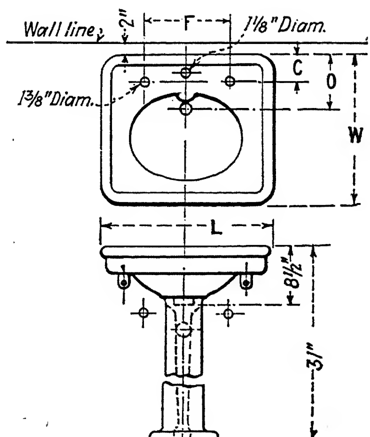


FIG. 196.—Standard dimensions of pedestal lavatories. (*Division of Simplified Practice.*)

Standard Types and Sizes

39. The following items are recommended as standard for the industry; and constitute a reduction to 58 from a previous 441 items.

Staple floor outlet siphon jet with silencing chamber:

Top supply, regular bowl.
Extended top supply, regular bowl.
Top supply, extended lip.
Extended top supply, extended lip.

Staple floor outlet siphon jet closet:

Top supply, regular bowl (regular height).
Extended top supply, regular bowl (regular height).
Top supply, extended lip (regular height).
Extended top supply, extended lip (regular height).
Top supply, extended lip (juvenile height).

Wall-hanging siphon jet closet:

Top supply, extended lip.
Back supply, extended lip.
Side supply, extended lip.

Staple floor outlet siphon jet with raised rear vent:

Top supply, extended lip (regular height).
Top supply, extended lip (juvenile height).

Wall-hanging jet closet with raised rear vent:

Top supply, extended lip.
Back supply, extended lip.
Side supply, extended lip.

Staple floor outlet reverse-trap closet:

Back supply, regular bowl (regular height).
Back supply, extended lip (regular height).

Staple floor outlet reverse-trap closet with jet:

Back supply, regular bowl (regular height).
Back supply, extended lip (regular height).

Staple floor outlet siphon washdown:

Back supply, regular bowl, 12-in. roughing (regular height).
Back supply, regular bowl, 14-in. roughing (regular height).
Back supply, regular integral seat, 12-in. roughing (regular height).
Back supply, regular integral seat, 14-in. roughing (regular height).

Staple floor outlet siphon washdown with jet:

Back supply, regular bowl (regular height).

Wall-hanging blowout closet:

Back supply, extended lip.
Side supply, extended lip.
Back supply, extended lip, integral seat.
Side supply, extended lip, integral seat.

Wall-hanging blowout closet with raised rear vent:

Back supply, extended lip.
Side supply, extended lip.

Low-down tank with upper left-hand lever:

Small (approximately 6-gal. capacity).
Large (approximately 8-gal. capacity).

High-up tanks, with center outlet and overtop supply. Where used, lever shall be on left side.

Small (approximately 3-gal. capacity).
Large (approximately 6-gal. capacity).

Note.—The above action eliminates all side supply water-closet bowls of the floor type, and all washdown water-closet bowls with extended lip.

LAVATORIES

40. It is recommended that all lavatories be made with an overflow; that standardized supply and waste punchings be limited, (*a*) for two lavatory faucets and pop-up waste or chain stay; or combination fitting; (*b*) for combination fitting for integral nozzle and pop-up waste.

Straight front lavatory:

18 by 20 in., with back.
18 by 20 in., without back.
20 by 24 in., with back.
20 by 24 in., without back.
22 by 27 in., without back.
24 by 30 in., without back.

Round-front lavatory:

18 by 20 in., with back.
18 by 20 in., without back.

Round-front corner lavatory:

16½ by 16½ in., with back.

18. Structural Slate.—The following is quoted from Simplified Practice Recommendation No. 13, approved Aug. 1, 1924, by the Division of Simplified Practice of the U. S. Department of Commerce:

In accordance with the unanimous action on Jan. 23, 1924, in New York, N. Y., of the joint conference of representatives of manufacturers, distributors, and users of structural slate for plumbing and sanitary purposes, the U. S. Department of Commerce, through the Bureau of Standards, recommends that recognized dimensions, sizes, and nomenclature be reduced to those shown below:

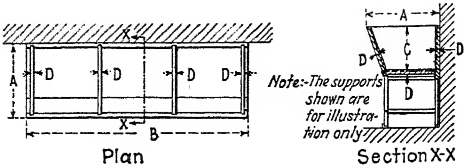


FIG. 197.—Slate laundry tubs with and without integral backs.
(Division of Simplified Practice.)

TABLE 137.—SLATE LAUNDRY TUBS—WITH OR WITHOUT INTEGRAL BACKS
(See Fig. 197)

Number of equal sized compartments	*A*	*B*	*C*	*D*
	Compartment width, inches	Length, inches	Inside depth, inches	Slate thickness, inches
1	24	24, 30, and 36	12 or 14	1¼
2	24	48, 54, and 60	12 or 14	1¼
3	24	72, 78, and 84	12 or 14	1¼

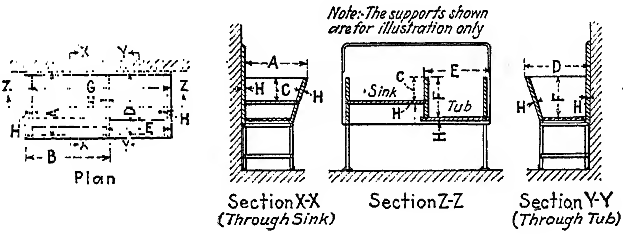


FIG. 198.—Sink and one-tub combination—with integral back.
(Division of Simplified Practice.)

TABLE 138.—SINK AND ONE TUB COMBINATION—WITH INTEGRAL BACK
(See Fig. 198)

Sink dimensions			Tub dimensions			Over-all dimensions	Slate thickness
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*
Outside width, inches	Outside length, inches	Inside depth, inches	Outside width, inches	Outside length, inches	Inside depth, inches	Outside length, inches	Inches
24	25¼	8	24	24	12 or 14	48	1¼
24	31¼	8	24	24	12 or 14	54	1¼
24	37¼	8	24	24	12 or 14	60	1¼

TABLE 139.—SINK AND TWO-TUB COMBINATION—WITH INTEGRAL BACK

Sink dimensions			Tub dimensions, over-all			Over-all dimensions outside length, inches	Slate thickness, inches
Outside width, inches	Outside length, inches	Inside depth, inches	Outside width, inches	Length two tubs, inches	Inside depth, inches		
24	26½	8	24	48	12 or 14	72	1¼
24	32½	8	24	48	12 or 14	78	1¼
24	32½	8	24	54	12 or 14	84	1¼
24	38½	8	24	48	12 or 14	84	1¼
24	38½	8	24	54	12 or 14	90	1¼

The outside length of the sink is determined by subtracting the outside length of the tub as given (and which is kept as a basic standard throughout) from the over-all length and adding the thickness of the partition (Table 138); or the thickness of the two partitions (Table 139).

It should be noted in Tables 138 and 139 that the over-all dimension is for the outside of the tub and sink combined. Some manufacturers extend the front, bottom, and back beyond the over-all length given here. The amount of this extension should be ascertained and taken into consideration when ordering this combination to fill a definite space.

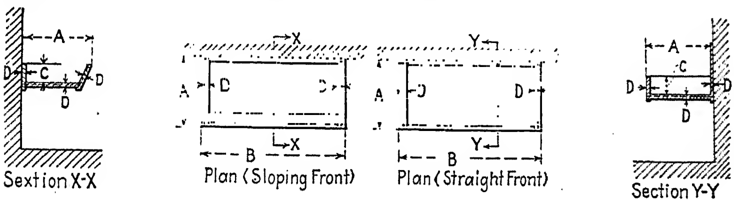


FIG. 199.—Sinks—with or without integral backs.
(*Division of Simplified Practice.*)

TABLE 140.—SINKS WITH OR WITHOUT INTEGRAL BACKS
(See Fig. 199)

A	B	C		D	A	B	C		D
Over-all width, inches	Over-all length, inches	Inside depth, inches	Style of front straight or sloping	Slate thickness, inches	Over-all width, inches	Over-all length, inches	Inside depth, inches	Style of front straight or sloping	Slate thickness, inches
12	18	6	Yes	1¼	22	36	6	Yes	1¼
18	24	6	Yes	1¼	22	42	6	Yes	1¼
20	30	6	Yes	1¼	24	30	6	Yes	1¼
20	36	6	Yes	1¼	24	36	6	Yes	1¼
22	30	6	Yes	1¼	24	48	6	Yes	1¼

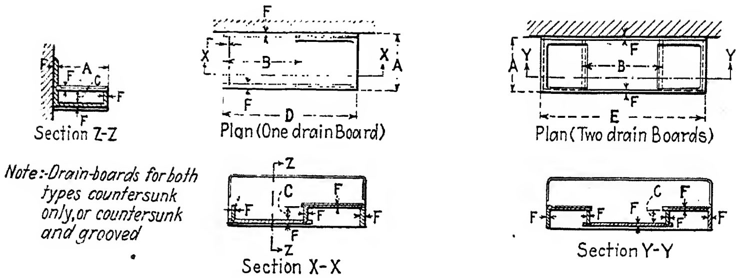


FIG. 200.—Sinks—with or without integral backs—with one or two drain boards.
(*Division of Simplified Practice.*)

TABLE 141.—SINKS[1]—WITH OR WITHOUT INTEGRAL BACKS—WITH ONE OR TWO DRAIN BOARDS

(See Fig. 200)

A	*B*	*C*	*D*	*E*	*F*	*A*	*B*	*C*	*D*	*E*	*F*
Over-all width, inches	Over-all length, inches	Inside depth, inches	One drain board[2] on right or left over-all length, inches	Two drain boards[2] over-all length, inches	Slate thickness, inches	Over-all width, inches	Over-all length inches	Inside depth, inches	One drain board[2] on right or left over-all length, inches	Two drain boards[2] over-all length, inches	Slate thickness, inches
12	18	6	42	54	1¼	22	36	6	60	72	1¼
18	24	6	48	60	1¼	22	42	6	56	78	1¼
20	30	6	54	66	1¼	24	30	6	54	66	1¼
20	36	6	60	72	1¼	24	36	6	60	72	1¼
22	30	6	54	66	1¼	24	48	6	72	84	1¼

[1] Extra apron or ends to be 1 inch in thickness—other sizes to fit.
[2] Regular type drain board, countersunk and grooved; or countersunk only.

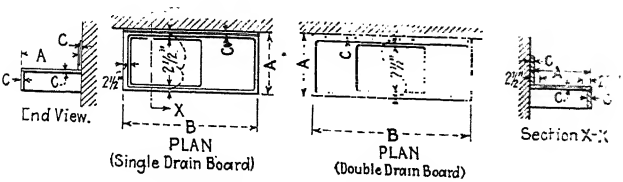


FIG. 201.—Slate sink tops only.
(*Division of Simplified Practice.*)

TABLE 142.—SLATE SINK TOPS AND SLOP HOPPERS. SLOP HOPPERS ARE WITH OR WITHOUT INTEGRAL BACKS

(See Fig. 201)

Slate sink tops only			Slop hoppers—with or without integral backs				
A	*B*	*C*					
Width of tops, inches	Length of tops, inches	Thickness of slate, inches	Over-all width, inches	Over-all length, inches	Inside depth, inches	Style of front	Slate thickness, inches
18 to 22	up to 78	1¼	24	24	12 or 14	Sloping	1¼
24 to 30	above 78	1¼	24	30	12 or 14	Sloping	1¼
			24	36	12 or 14	Sloping	1¼

The regular type of top, grooved and countersunk or countersunk only, surrounds the sink with an integral slate rim. The over-all dimensions of such tops depend upon the size of the sink openings, and are governed by the inclusion of a single or a double drain board. The width of the top must be sufficient to provide a 2½ in. slate rim at both the back and the front of the sink opening. The over-all length of top, with single drain board end must provide 2½ in. of slate on remaining three sides of sink. Single drain boards, measuring from sink opening, should be 24 in. in length, and double drain boards 18 in. in length.

Slate tops can also be furnished with separate aprons or separate backs.

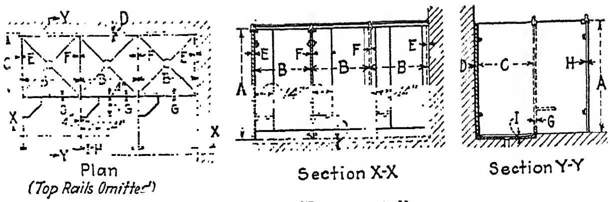


FIG. 202.—Shower stalls.
(Division of Simplified Practice.)

TABLE 143.—SHOWER STALLS
(See Fig. 202)

A	*B*		*C*		Thickness of slate					
					D	*E*	*F*	*G*	*H*	*I*
Stall height	Stall width		Stall depth		Backs, inches	Ends, inches	Partitions, inches	Curbs, inches	Stiles, inches	Floor slabs, inches
	Feet	Inches	Feet	Inches						
6 ft. 6 in. and 7 ft. 0 in.	3	0	3	0	1	1	1	1¼	1¼	2
	3	0	3	6	1	1	1	1¼	1¼	2
	3	6	3	6	1	1	1	1¼	1¼	2

Where one floor drain serves several showers, the partitions are 5 ft. 6 in. high and are supported by legs 1 ft. in length.

Floor slabs 2 in. thick, sloping to drain outlet in center.

In types where slate dressing rooms are placed in front of shower stalls, separate slabs are extended to line with partitions and ends, forming compartments 6 in. less in depth than shower stalls. Shower stalls are moved to front of dressing compartments and 14-in. covering separations are placed between them and stalls from top of curbs to top of shower stalls. A 14-in. diagonal slate seat is fastened to wing and end, or partition.

TABLE 144.—TOILET ENCLOSURES

Stall height, feet	Stall width		Stall depth inside		Thickness of slate				
	Feet	Inches	Feet	Inches	Backs, inches	Ends, inches	Partitions, inches	Stiles, inches	Floor slabs, inches
6 and 7	2	6	3	6	1	1	1	1¼	1¼
	2	8	4	0					
	2	10	and						
	3	0	4	6					

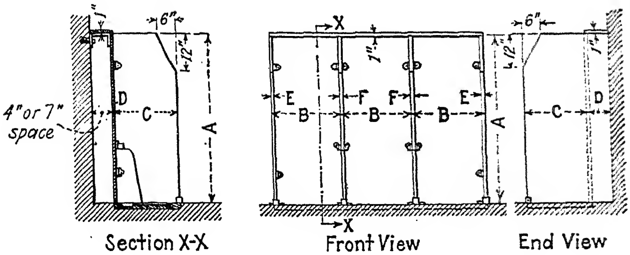


FIG. 203.—Urinals.

TABLE 145.—URINALS
(See Fig. 203)

With partitions						Without partitions						Thickness of slate		
A Height		*B* Width		*C* Depth inside		Height		Width inside		Inside depth of ends		*D* Backs, inches	*E* Ends, inches	*F* Partitions, inches
Feet	Inches	Feet	Inches	Feet	Inches	Feet	Inches	Feet	Inches	Feet	Inches			
4	0	1	8	1	8			2	0					
4	6	2	0	1	2	4	6	4	0					
5	0	2	0	1	6	and		6	0					
5	6	2	0	1	8	5	0	8	0	1	8	1	1	1
								10	0					
								12	0					
								14	0					

The top front edges of all urinal stall partitions and ends are to be rounded to a 6-in. radius, or cut to a slope of 6 in. back and 12 in. down.

Backs that measure from 6 to 9 ft. in length may be made up of two pieces, while those measuring over 9 ft. in length may be made up of three pieces. Gutters (where used) are hollowed out of solid slate, and two or more pieces may be used in constructing total lengths of 6 and 9 ft.

Floor slabs are $1\frac{1}{2}$ or 2 in. in thickness and should line up with face of ends.

A corner urinal stall is made by forming an angle with two slate ends, and setting the same snugly into the corner of the wall, upon a countersunk floor slab $1\frac{1}{2}$ in. in thickness to the outer edge of backs. The angle is formed by placing a 21- or a 24-in. slate end against a 22- or a 25-in. slate end, so that the outside face of the former is in line with the thickness of the latter.

The 4- or 7-in. spaces to be covered at top with 1-in. slate, to fit. The exposed ends to be covered by increasing the depth of the end slabs. For the back-to-back type, the end slabs to be made in one piece for the purpose of covering both sets of stalls and the vent spaces.

All partitions (see tables 143, 144, 145) and ends are placed against backs so that the depth of stall or inclosure and the inside dimension of same are identical. But for batteries of two or more the widths of all except the end stalls or inclosures are taken as being the distance between the center line of the partitions. In order that all back slabs may be of the same dimensions, the width of the end stalls or inclosures is the distance between the center line of the partition, and the outside face of the end slabs. Vent spaces, 7 in. in width to be provided.

Working spaces 18 in. wide are covered and closed with slate 1 in. in thickness at free standing ends.

In back to back batteries, working space is 30 in., and where neither vent nor working space is required one back slab is sufficient.

Floor slabs with plain or beveled edges, flat or countersunk surfaces, are made in sizes to fit the above standard. The size and location of all pipe openings should be mentioned in all specifications.

Unless otherwise specified all exposed surfaces of slate, including both sides of all end and partition slabs (whether against the wall or not), are to be furnished with the standard sand-rubbed finish.

It is believed that the above sizes of slate will contribute to the convenience of architects and builders in preparing plans and specifications, and will be helpful to owners and buyers in buying units of slate.

19. Brass Lavatory and Sink Traps.—The following is quoted from Simplified Practice Recommendation No. 21, approved Aug. 6, 1924, by the Division of Simplified Practice of the U. S. Department of Commerce:

In accordance with the unanimous action of the general conference of representatives of manufacturers, distributors, and users of brass lavatory and sink traps, the U. S. Department of Commerce, through the Bureau of Standards, recommends that the recognized sizes, styles, and gages of brass lavatory and sink traps be reduced to the list shown in Table 146.

It is further recommended that:

1. All traps be listed and supplied less connections.
2. All traps be stamped with the name of the manufacturer and gage.
3. Elimination of all gages except No. 20 B. & S. and No. 17 B. & S. gage. (Every effort to be made to bring practice to use No. 17 B. & S. gage minimum, thus reducing the present variety and adopting one standard gage for all types of traps.)
4. All crown-vented traps to be eliminated.
5. All traps made in accordance with special city codes, such as Kansas City, Los Angeles, and Cleveland, to be eliminated. (The elimination under items 4 and 5 were intended as a step forward, as sufficient combinations and types were included in the recognized varieties to meet all local conditions. Local health authorities and engineers are urged to revise codes and specifications in order to keep abreast of the advance in practice as recommended by the industry.)

TABLE 146.—DIMENSIONS OF BRASS LAVATORY AND SINK TRAPS

Wrought traps					Cast bend traps					Wrought sink traps			
Size, inches	Gage	Style	Inlet, inches	Clean-out	Size, inches	Gage	Style	Inlet, inches	Clean-out	Size, inches	Gage	Style	Inlet, inches
1¼	20	P	1¼	No	1¼	20	P	1¼	No	1¼	17	P	1¼
1¼	20	P	1¼	Yes	1¼	20	P	1¼	Yes	1¼	17	P	1¼
1¼	20	S	1¼	No	1¼	20	S	1¼	No	1½	17	P	1¼ or 1½
1¼	20	S	1¼	Yes	1¼	20	S	1¼	Yes	1½	17	P	1¼ or 1½
1¼	20	S[1]	1¼	Yes	1¼	20	S[1]	1¼	Yes				
1¼	20	S[1]	1¼	No	1¼	20	S[1]	1¼	No	Wrought antisiphon traps (Clean sweep or ball pattern with cleanout)			
1¼	17	P	1¼	No	1¼	17	P	1¼	No				
1¼	17	P	1¼	Yes	1¼	17	P	1¼	Yes	1¼	20	P	1¼
1¼	17	S	1¼	No	1¼	17	S	1¼	No	1½	20	P	1¼ or 1½
1¼	17	S	1¼	Yes	1¼	17	S	1¼	Yes	1¼	20	S	1¼
1¼	17	S[1]	1¼	Yes	1¼	17	S[1]	1¼	Yes	1½	20	S	1¼ or 1½
1¼	17	S[1]	1¼	No	1¼	17	S[1]	1¼	No	1¼	17	P	1¼
1½	20	P	1¼ or 1½	No	1½	20	P	1¼ or 1½	No	1½	17	P	1¼ or 1½
1½	20	P	1¼ or 1½	Yes	1½	20	P	1¼ or 1½	Yes	1¼	17	S	1¼
1½	20	S	1¼ or 1½	No	1½	20	S	1¼ or 1½	No	1½	17	S	1¼ or 1½
1½	20	S	1¼ or 1½	Yes	1½	20	S	1¼ or 1½	Yes	Cast antisiphon traps (Clean sweep or ball pattern with cleanout)			
1½	20	S[1]	1¼ or 1½	Yes	1½	20	S[1]	1¼ or 1½	Yes				
1½	20	S[1]	1¼ or 1½	No	1½	20	S[1]	1¼ or 1½	No				
1½	17	P	1¼ or 1½	No	1½	17	P	1¼ or 1½	No	1¼	20	P	1¼
1½	17	P	1¼ or 1½	Yes	1½	17	P	1¼ or 1½	Yes	1½	20	P	1¼ or 1½
1½	17	S	1¼ or 1½	No	1½	17	S	1¼ or 1½	No	1¼	20	S	1¼
1½	17	S	1¼ or 1½	Yes	1½	17	S	1¼ or 1½	Yes	1½	20	S	1¼ or 1½
1½	17	S[1]	1¼ or 1½	Yes	1½	17	S[1]	1¼ or 1½	Yes	1¼	17	P	1¼
1½	17	S[1]	1¼ or 1½	No	1½	17	S[1]	1¼ or 1½	No	1½	17	P	1¼ or 1½
										1¼	17	S	1¼
										1½	17	S	1¼ or 1½

New York and Boston regulation traps

1¼	P	1¼[2]	1¼	Bag offset	1¼ in. tubing outlet
1½	P	1½ or 1¼[2]	1½		1½ or 1¼ in. tubing outlet
2	P	2½ or 1¼[2]	1¼		1¼ in. I P outlet
1½	P	1½ or 1¼[3]	1½		1½ or 1¼ in. I P outlet

[1] 26 in. over-all.
[2] External. Antisiphon traps (S) to be furnished with either straight or offset outlet tube as required.
[3] Internal.

20. Cold-water Meters. Standards of the American Waterworks Association.—The standard specifications for disc meters were adopted June 9,1921, and for current, compound, and fire service meters on May 24, 1923. The dimensions and capacities of disc meters, current meters and compound meters are shown in Table 147.

TABLE 147.—DIMENSIONS AND CAPACITIES OF STANDARD METERS
(American Waterworks Association Standards)

Size, inches	Length, inches	Tail piece, length, inches	Spuds threaded,[1] inches	Tail pieces outside thread,[1] inches	Nuts threaded,[1] inches	Bushings, inches	Maximum indication of initial dial, cubic feet	Minimum capacity of register 100,000 cubic feet	Normal test flow, g.p.m.	Minimum test flow, g.p.m.	Capacity at 25 pounds per square inch loss in pressure, g.p.m.
Disc meters											
5/8	7 1/2	2 3/8	3/4	1/2	3/4	....	1	1	1 to 20	1/4	20
3/4	9	2 1/2	1	3/4	1	....	10	10	2 to 34	1/2	34
1	10 3/4	2 5/8	1 1/4	1	1 1/4	....	10	10	3 to 53	3/4	53
1 1/2	12 5/8	2 7/8	1 1/2	1 1/2	2	2 by 1 1/2	10	10	5 to 100	1 1/2	100
2	15 1/4	3	2	2	2 1/2	2 1/2 by 2	10	100	8 to 160	2	160
3	24	...	Flanged[2]	...	...	....	10	100	16 to 315	4	315
4	29	...	Flanged[2]	...	...	....	100	1,000	28 to 500	7	500
6	36 1/2	...	Flanged[2]	...	...	....	100	1,000	48 to 1,000	12	1,000
Compound meters											
1 1/2	......	2 7/8	Flanged[1] or tapped[2]	1 1/2	2	2 by 1 1/2	10	100	2 to 100	1/2	100
2	......	3	Flanged[2] or tapped[2]	2	2 1/2	2 1/2 by 2	10	100	2 to 160	1/2	160
3	......	...	Flanged[2]	...	...	....	10	100	4 to 315	1	315
4	......	...	Flanged[2]	...	...	....	100	100	6 to 500	1 1/2	500
6	......	...	Flanged[2]	...	...	....	100	1,000	10 to 1 000	3	1,000
8	......	...	Flanged[2]	...	...	....	1,000	1,000	16 to 1,600	4	1 600
10	......	...	Flanged[2]	...	...	....	1,000	1,000	32 to 2,300	8	2,300
12	......	...	Flanged[2]	...	...	....	1,000	1,000	32 to 3,100	14	3,100
Current meters											
1 1/2	15 1/4*	2 7/8	1 1/2	1 1/2	2	2 by 1 1/2	10	100	12 to 100	5	100
2	19	3	2	2	2 1/2	2 1/2 by 2	10	100	16 to 175	7	175
3	24	...	Flanged or bell[3] and spigot	...	...	....	10	100	24 to 400	10	400
4	29 1/4	...		...	...	....	100	100	40 to 700	15	700
6	36 3/4	...		...	...	....	100	1,000	80 to 1,600	30	1,600
8	48 3/4	...		...	...	....	1,000	1,000	144 to 2,800	50	2,800
10	60	...		...	...	....	1,000	1,000	224 to 4,375	75	4,375
12	70	...		...	...	....	1,000	10,000	320 to 6,400	100	6,400

[1] Briggs standard pipe thread.
[2] American Standard, 1924.
[3] American Waterworks Association Standard, Class B.
* The figures in this column represent maximum lengths. Minimum lengths are as follows: 1 1/2 = 13 in.; 2 = 15 1/4 in.; 3 = 20 in.; 4 = 22 in.; 6 = 42 in.; 8 = 26 3/4 in.; 10 = 30 in.; 12 = 36 in.

Disc-type Meters

Cases.—All meters shall have an outer case with a separate inner chamber in which the disc operates. The outer case for all 2-in. and smaller meters shall be of bronze composition. Cast-iron frost bottoms may be provided. The outer case for meters larger than 2-in. shall be of bronze composition or of cast-iron protected by a non-corrosive treatment.

All meters shall have cast on them in raised characters the size and the model and the direction of the flow through the meter shall be properly indicated. Meters larger than 1 in. shall be designed for easy removal of all interior parts without disturbing the connections to the pipe line.

External Bolts.—All external bolts shall be made of bronze or of galvanized iron or steel. Nuts shall be designed for easy removal after having been long in service.

Registers.—Registers may be either round or straight reading, indicating in cubic feet or gallons.

All parts of the registers shall be made of non-ferrous material.

All dials, including the initial dial, shall be divided into ten equal parts. All hands or pointers shall taper to a sharp point. They shall be accurately set and securely held in place.

Register Boxes.—Register boxes and lids shall be made of bronze composition or same material as the top case, with the name of the manufacturer cast on the lid in raised letters. The serial number of the meter shall be plainly stamped on the lid. If required, the serial number shall also be stamped on the case. The lid shall be recessed and shall lap over the box to prevent dirt from accumulating on the glass. The glass shall be inserted from the inside and shall be securely held in place without the use of putty or pins. All register compartments shall be provided with a water escape hole $\frac{1}{8}$ in. in diameter, so placed that the change gear or registering mechanism cannot be tampered with.

Connections for Meters (see Table 147).

Seal Wire Holes.—All $\frac{5}{8}$, $\frac{3}{4}$, 1, $1\frac{1}{2}$, and 2-in. meters shall have register box screws and coupling nuts drilled for seal wire holes. Meters larger than 2 in. in size shall have register box screws drilled for seal wire holes. All seal wire holes shall be not less than $\frac{3}{32}$ in. in diameter.

Measuring Chambers.—The measuring chamber for all meters shall be made of bronze composition and shall not be cast as part of the outer casing. It shall be machined with great care and secured in position in the outer casing so that any slight distortion of the casing, which might take place under 150 lb. working pressure will not affect the sensitiveness of the meter.

Discs.—Disc pistons shall be made of vulcanized rubber and shall be fitted accurately but freely in their chambers. Vulcanized rubber pistons shall have a metal reinforcement or a thrust roller.

Intermediate Gear Trains.—The intermediate gear trains shall be of such construction as to be easily removed and shall be made throughout of non-ferrous material. Gear spindles may run in bearings bushed with hard rubber, provided the bushings are so constructed that they cannot drop out.

Strainers.—All meters shall be provided with strainers except when self-strained by means of an annular space between the measuring chamber and

the external case. Strainers shall be made of non-ferrous materials and shall fit tightly against the wall of the casing. They shall have an effective straining area as large as practicable and at least double that of the inlet.

Registration.—The registration on the meter dial shall indicate the quantity recorded to be not less than 98 per cent nor more than 102 per cent of the water actually passing through the meter while it is being tested at rates of flow within the limits specified in Table 147 under "normal test-flow limits." There shall be not less than 90 per cent of the actual flow recorded when a test is made at the rate of flow set forth under "minimum test flow."

Capacity (see Table 147).

Pressure Test.—Disc meters shall be guaranteed to operate under a working pressure of 150 lb. per square inch without leakage or damage to any part.

Workmanship and Material.—Disc meters shall be guaranteed against defects in materials and workmanship for a period of 1 year from date of shipment. Parts to replace those in which a defect may develop within such a period shall be supplied without charge, piece for piece, upon the return of such defective parts to the manufacturer thereof or upon proper proof of such defect.

Rejected Meters.—The manufacturer shall at his own expense replace or satisfactorily readjust all meters rejected for failure to comply with these specifications.

Current type and compound type meters are less frequently installed by the plumber. In many respects the specifications are quite similar to those for disc meters. Hence, only those portions of the standard specifications which differ materially from those for disc meters are quoted.

Current Type Meters

Measuring Wheels.—The measuring wheel for all meters shall be made of vulcanized rubber. The measuring wheel shall be mounted, or shall rotate, on phosphor-bronze or other suitable metal spindle and shall be supported by jewel, ball, or other suitable bearings. Measuring wheels mounted on spindles shall revolve in hard-rubber bushed gearings. The measuring wheel, together with its spindle, shall be as nearly as possible of the same specific gravity as water.

Registration.—The registration on the meter dial shall indicate the quantity recorded to be not less than 97 per cent, nor more than 103 per cent of the water actually passed through the meter while it is being tested at rates of flow within the limits specified in Table 147 under "normal test flow limits."

Compound-type Meters

Registration.—The registration on the meter dials shall indicate the quantity recorded to be not less than 97 per cent nor more than 103 per cent of the water actually passed through the meter while it is being tested at rates of flow within the limits specified in Table 147 under "normal test flow limits," except in the registration of flows within the "change over" from by-pass meter to main-line meter. The registration at these rates of flow shall not

be less than 85 per cent. The difference in the rate of flow at the beginning and the end of the "change over" shall not exceed the figures given in Table 147.

The beginning of the "change over" is when the accuracy falls below 97 per cent due to the automatic valve mechanism, and the end of the "change over" period is when the accuracy of registration again reaches 97 per cent.

There shall not be less than 90 per cent of the actual flow recorded when a test is made at the rate of flow set forth in Table 147 under "minimum test flow."

APPENDIX II

DEFINITIONS

Alligator Wrench.—A wrench with toothed V-shaped jaws fixed in position.

Back-flow.—Flow of water or sewage opposite to the normal direction of flow.

Back-pressure.—Air pressure in pipes greater than atmospheric pressure.

Back Vent Pipe.—That part of a vent line which connects directly with an individual trap underneath or back of the fixture and extends to the branch or main, soil or waste pipe at any point higher than the fixture or fixture trap it serves (see Fig. 96).

Ball Cock.—A faucet opened or closed by the fall or rise of a ball floating on the surface of water.

Ball Joint.—A connection in which a ball is held within a cup-like shell which allows movement in any direction.

Bell or Hub.—That portion of a pipe which, for a short distance, is sufficiently enlarged to receive the end of another pipe of the same diameter for the purpose of making a joint.

Bending Pin (or Iron).—A tool used for straightening or expanding lead pipe.

Bibb.—Synonymous with faucet, cock, tap, plug, etc. The word faucet is preferred.

Bi-transit Waste.—A standing overflow

Block Tin.—Pure tin.

Bonnet.—That portion of a gate valve into which the disc rises when the valve is opened.

Bossing Stick.—A wooden tool for shaping lead for tank lining.

Bull-headed Tee.—A tee in which the branch is larger than the run.

Burr.—Roughness or extra metal protruding from the walls of a pipe usually as a result of cutting of the pipe.

Bushing.—A plug designed to be threaded into the end of a pipe. The plug is bored and tapped to receive a pipe of smaller diameter than that of the pipe into which it is screwed.

By-pass.—Any method by which water may pass around a fixture, appliance, connection, or length of pipe. Sometimes applied to an erroneous connection between a drain pipe and a vent pipe which will allow sewer air to enter the building.

By-pass Vent.—See page 167, and Fig. 101

Caliber.—Internal diameter or bore.

Cap.—A fitting into which the end of a pipe is fitted for the purpose of closing the end of the pipe.

Catch Basin.—A receptacle in which liquids are retained for a sufficient period to deposit settleable material.

Caulking.—Plugging an opening with oakum, lead, or other material which is pounded into place.

Cesspool.—A pit for the reception or detention of sewage.

Chain Tongs.—A tool used for holding pipe from turning or to turn the pipe. It consists of a heavy bar with sharp teeth at one end. These teeth are held firmly impressed in the pipe by means of a chain wrapped round the pipe and attached to the bar.

Chase.—A recess in a wall for the purpose of holding pipes or conduits passing from floor to floor.

Check Valve.—A valve which automatically closes to prevent the back flow of water.

Chipping Knife.—A knife used for whittling or cutting lead.

Circuit Vent.—See *loop vent.*

Close Nipple.—A fitting with outside threads only, used for connecting two pipes. The length of the threads is the shortest permissible for standard practice.

Closet Bolt.—A bolt used for fastening a closet bowl to the floor.

Closet Screw.—A long screw with a detachable head; used for fastening a closet bowl to the floor.

Cock.—See *faucet* or *bibb.*

Combination Fixture.—A plumbing fixture including a sink and wash tray combined in one fixture.

Combined Sewer.—A sewer intended for the carriage or both sewage and storm, surface, and ground water.

Compression Faucet or Valve.—A faucet or valve in which the flow of water is shut off by means of a flat disc (either with or without packing) which is screwed down onto its seat.

Conductor or Leader.—A pipe to convey rain water.

Continuous Vent.—A continuation of a vertical or approximately vertical waste pipe above the connection at which liquid wastes enter the waste pipe. The extension may or may not continue in a vertical direction (see Figs. 95 and 96).

Copper Bit.—A tool used for soldering. Usually called a soldering iron.

Corporation Cock.—A valve placed in a service pipe close to its connection with a water main.

Coupling.—A fitting with inside threads only, used for connecting two pieces of pipe.

Cowl.—A hood on the top of a vent pipe or soil stack.

Cross.—A fitting used for connecting four pieces of pipe at right angles.

Crown.—The crown of a trap. This is the part of a trap in which the direction of flow is changed from an upward to a downward direction (see Fig. 204).

Crown Vent.—A vent pipe connected at the crown of a trap (see Fig. 98).

Crown Weir.—The highest portion of the inside bottom surface at the crown of a trap (see Fig. 204).

Curb Box.—A device consisting usually of a long piece of pipe or tube-like casing, placed over a curb cock, through which a key is inserted to permit the turning of the curb cock.

Curb Cock.—A valve placed in a service pipe at a point near the curb.

Cup Joint.—A lead pipe joint in which one end of the pipe is opened enough to receive the tapered end of the adjacent pipe.

Dead End.—The extended portion of a pipe which is closed at one end and to which no connections are made on the extended portion thus permitting the stagnation of water or air therein.

Deep-seal Trap.—A trap with a seal of 4 in. or more.

Die.—A tool used for cutting threads.

Dip of a Trap.—The lowest portion of the inside top surface of the channel through the trap (see Fig. 204).

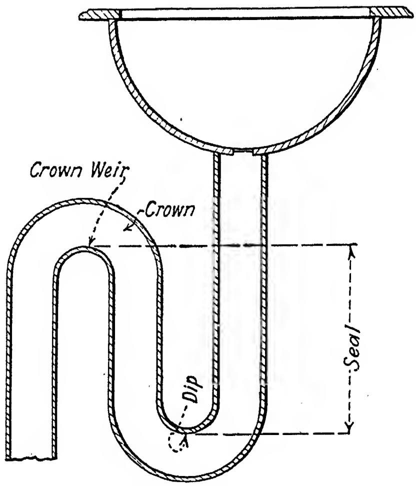


FIG. 204.—Parts of a trap.

Domestic or Sanitary Sewage.—See *sanitary sewage.*

Dope.—A compound used in making connections on threaded pipe.

Downspout.—The vertical portion of a rain-water conductor.

Drain.—A sewer or other pipe or conduit used for conveying ground, surface, or storm water.

Drainage Fitting.—A cast-iron threaded fitting used on drainage pipes. A distinctive feature is the shoulder against which the connecting pipe rests so as to present a smooth and continuous interior surface. Sometimes called a Durham fitting.

Dresser.—A tool used for straightening lead pipe and sheet lead.

Drift.—To drive a wooden plug through a lead pipe or trap to remove dents.

Drift Plug.—The plug used in drifting.

Drop Ell.—An ell with lugs in the sides by means of which it can be attached to a support.

Drop Tee.—A tee with lugs in the sides by means of which it can be attached to a support.

Drum Trap.—A trap consisting of a cylinder with its axis vertical. The cylinder is larger in diameter than the inlet or outlet pipe. The cylinder is usually about 4 in. in diameter with $1\frac{1}{2}$-in. inlet and outlet pipes.

Durham Fitting.—See *drainage fitting.*

Dutchman.—A lead nipple not more than about 1 in. long which is placed in a wiped joint to make up the desired length in joining two pipes which are too short.

Eccentric Fitting.—A fitting in which the center line of the run is offset in the fitting.

Elbow.—A fitting joining two pipes at an angle.

Electrolysis.—Corrosion resulting from electric currents.

Ell.—Same as *elbow.*

Escutcheon.—A flange used on nickeled pipe to cover a floor, wall, or other opening.

Faucet or Cock.—A valve on a water pipe by means of which water can be drawn from or held within the pipe.

Female Thread.—A thread on the inside surface of a pipe or fitting. Preferably called an inside thread.

Ferrule.—A metallic sleeve, calked or otherwise joined to an opening in a pipe, into which a plug is screwed which can be removed for the purpose of cleaning or examining the interior of the pipe.

Finishing.—All work done after the roughing-in.

Fittings.—Parts of a pipe line other than straight pipe or valves, such as couplings, elbows, tees, crosses, unions, increasers, etc.

Fixture.—A receptacle, attached to a plumbing system, other than a trap, in which water or wastes may be collected or retained for ultimate discharge into the plumbing system.

Flange Union.—A pair of flanges to be threaded on to the ends of pipes to be joined. The flanges are bolted together when the pipes are joined.

Flashing.—A piece of sheet metal fitted under another piece of flat metal or wood over which water is expected to run.

Flush Bushing.—A bushing, without a shoulder, which fits flush into the fitting with which it is to connect.

Flush Valve.—A valve used for flushing a fixture by using water directly from the water-supply pipes or in connection with a special flush tank.

Flux.—Material used for aiding in making solder flow and to prevent the oxidation of the materials to be soldered.

Follower.—Part of a threading tool which keeps the thread straight.

Fresh-air Inlet.—A connection made to a house drain above the house or main trap, leading to the outside atmosphere (see numbers 79, 164, and 167 in Fig. 109).

Frost-proof Closet.—A long-hopper closet in which the water in the trap is placed below the frost line.

Fuller Faucet.—A faucet in which the flow of water is stopped by means of a rubber ball which is forced into the opening (see Fig. 65).

Gasket.—Packing, of any material, placed between two metal or similar surfaces, which are to be drawn together in a water-tight or air-tight joint.

Gate Valve.—A valve in which the flow of water is cut off by means of a circular disc, fitting against machine-smoothed faces, at right angles to the direction of flow. The disc is raised or lowered by means of a threaded stem connected to the handle of the valve. The opening in the valve is usually as large as the diameter of the pipe (see Fig. 49).

Globe Valve.—A valve in which the flow of water is cut off by means of a circular disc which fits against the valve seat. The plane of movement of the disc is paralled to the normal direction of flow of water, which is turned through a tortuous passage to direct the flow normal to the face of the disc (see Fig. 51).

Goose Neck.—A return bend of small-sized pipe one end of which is about 1 ft. long and the other about 3 in. long. It is commonly used as a faucet for a pantry sink. The same term is used for the lead connection between a service pipe and a water main, as illustrated in Fig. 2.

Ground Joint.—A machined metal joint which fits tightly without gasket or packing.

Ground-key Valve or Faucet.—A valve or faucet through which the rate of flow of water is controlled by means of a circular plug or key which fits closely in a cylindrically or conically ground seat. The plug has a hole bored through it as the waterway. When the hole is in line with the run the valve is open; when turned at right angles to the run the valve is closed (see Fig. 53).

Ground Water.—Water that is standing in or passing through the ground.

Hatchet Iron.—A special form of soldering iron.

House Drain.—That part of the lowest horizontal piping of a plumbing system which receives the discharge from soil, waste, and other drainage pipes inside of any building and conveys the same to the house sewer.

House Sewer.—That part of the horizontal piping of a plumbing system extending from a point 4 ft. from the outside of the foundation of a building to the junction with another sewer or to a point of treatment or discharge, and conveying the drainage of but one building site.

House Slant.—A T or Y connection in a sewer for the purpose of receiving the connection of a house sewer.

Hub.—The bell end or enlarged end of a cast-iron or vitrified-clay pipe.

Hydrant.—A valve or faucet for the drawing of water from a pipe. The term is usually applied to an outside fixture for supplying a relatively large quantity of water for sprinkling, watering, fire protection, etc.

Increaser.—A coupling with one end larger than the other.

Industrial Wastes.—The liquid wastes resulting from the processes employed in industrial establishments.

Invert.—The lowest portion of the inside of any pipe or conduit which is not vertical.

Joint Runner.—An incombustible type of packing usually used for holding lead in the bell in the pouring of lead joints.

Journeyman Plumber.—A plumber who does plumbing work for another for hire.

Lap Weld.—A weld in which two metal surfaces are connected by lapping one over the top of the other. Frequently used for making small-sized iron pipe.

Latrine.—A water closet consisting of a continuous trough containing water. The trough extends under two or more adjacent seats.

Lavatory.—A fixture designed for the washing of the hands or face. Sometimes called a wash basin.

Leaching Cesspool.—A cesspool that is not water tight.

Lead Burning.—Welding lead.

Leader.—See *conductor*.

Lead Tacks.—Pieces of lead which are soldered to lead pipe so that it can be attached to a support.

Lead Wool.—Shredded lead. Used frequently in packing lead joints, particularly in wet places.

Length of Pipe.—The length as measured along the center line.

Local Vent.—A pipe or shaft serving to convey foul air from a plumbing fixture or a room to the outer air.

Lock Nut.—A nut which is screwed up tightly against another nut to prevent it becoming loosened.

Long Screws.—A nipple 6 in. long with one thread much longer than the ordinary thread.

Loop or Circuit Vent.—A continuation of a horizontal soil or waste pipe beyond the connection at which liquid wastes from a fixture or fixtures enter the waste or soil pipe. The extension is usually vertical immediately beyond its connection to the soil or waste pipe. The base of the vertical portion of the vent may be connected to the horizontal portion of the soil or waste stack between fixtures connected thereto (see Figs. 94 and 110).

Male Thread.—A thread on the outside of a pipe or fitting. Preferably called an outside thread.

Malleable Iron.—Cast iron which has been specially heat treated so as to render it less brittle than ordinary cast iron.

Manhole.—An opening constructed in a sewer, or any portion of a plumbing system, of sufficient size to permit a man to gain access thereto.

Master Plumber.—One with knowledge of and experience in plumbing who employs journeymen plumbers or who conducts a plumbing business.

Muffler.—A strainer designed to be inserted in a valve so as to diminish the sound of water passing through it.

Needle Valve.—A valve in which the opening, consisting of a small hole, is opened or closed by means of a long needle-like spindle which is thrust into or withdrawn from the hole.

Nipple.—A short piece of pipe with outside threads, used for connecting pipes or fittings.

Non-siphon Trap.—See Sec. 113.

Nozzle.—The outlet from a faucet or the end of a pipe line, so designed that the issuing stream of water is thrown in a shape or size different from the diameter of the pipe.

Oakum.—Hemp or old hemp rope soaked in oil to make it waterproof.

Packing.—A soft material placed about a joint into which it is squeezed to prevent the passage of liquid or gas.

Pedestal Urinal.—A urinal supported on a single pedestal and not connected to a wall for support.

Pet Cock.—A ground key faucet with an opening about $\frac{1}{8}$ in. in diameter (see Fig. 67). Sometimes called an air cock.

Pilot Light.—A small flame, used in gas-heating devices, which burns constantly to ignite the main gas supply when it is turned on.

Pipe Wrench.—See *stillson wrench*.

Plumber.—One experienced in the art of plumbing.

Plumber's Friend.—A cup-shaped device of rubber on the end of a wooden or metal handle; used for forcing out stoppage in pipes.

Plumber's Furnace.—A gasoline or kerosene firepot used for melting solder or heating soldering irons, etc.

Plumber's Rasp.—A coarse rasp used for filing lead.

Plumber's Round Iron.—A special form of soldering iron used in soldering seams in tanks.

Plumber's Soil.—A mixture of lampblack and glue used in lead work.

Plumbing.—The art of installing in buildings the pipes, fixtures, and other apparatus for bringing in the water supply and removing liquid and water-carried wastes.

Plumbing System.—The plumbing system of a building includes the water distributing pipes; the fixtures and fixture traps; the soil, waste, and vent pipes; the house drain and house sewer; the storm-water drainage; and ejectors; all with their devices, appurtenances, and connections all within or on a building or premises.

Plug Cock.—See *ground-key faucet.*

Pop Valve.—A safety valve which is kept closed by the pressure of a spring against the valve.

Pothook.—A hook used for lifting the lead pot from the furnace.

Private Sewer.—A privately owned sewer.

Privy.—An outhouse or structure used for the deposition of human excrement.

Privy Vault.—A pit beneath a privy in which human excrement collects.

Public Sewer.—A publicly owned sewer.

Range Closet.—A battery of seats placed close together, or one continuous opening in a seat, all placed above a single water-bearing trough or receptacle, designed to receive human fecal matter.

Reducer.—See *increaser.*

Revent.—A branch vent pipe; sometimes called a back-vent pipe.

Roughing-in.—The installation of all pipes in the drainage system and such water pipes as are in partitions and under floors. It includes all of the plumbing work except the setting of the fixtures. This latter work is known as the finishing.

Run.—That portion of a pipe or fitting continuing in a straight line in the direction of flow of the pipe to which it is connected.

Saddle Fitting.—A fitting clamped to the outside of a pipe, the joint being made tight with a gasket.

Safe.—A pan or other collector placed beneath a pipe or fixture to prevent leakage from escaping on to the floor, ceiling, or walls.

Safe Waste.—The waste pipe from a safe.

Sand Trap.—A catch basin for the collection of sand or other gritty material.

Sanitary or Domestic Sewage.—Sewage from buildings used for human habitation or occupancy.

Sanitary Sewer.—A sewer intended to receive sanitary sewage with or without industrial wastes and without the admixture of surface or storm water.

Seal.—The vertical distance between the dip and the crown weir of a trap (see Fig. 204). Also the water in the trap between the dip and the crown weir thereof.

Self-siphonage.—The breaking of the seal of a trap as the result of removing the water therefrom by the discharge of a fixture through the trap.

Septic Tank.—A tank through which sewage flows and which permits solids in the sewage to settle in order that portions of such solids may be disintegrated.

Service Box.—See *curb box.*

Service Ell.—A 45 or 90 deg. bend with an outside thread on one end and an inside thread on the other.

Service Pipe.—The pipe from the water main or source of supply to the building served.

Service Tee.—A tee with an outside thread on one end and an inside thread on the other end and on the branch.

Sewage.—The liquid wastes conducted away from residences, business buildings, or institutions, together with those from industrial establishments; and with such ground, surface. and storm water as may be present.

Sewer.—A conduit for carrying off sewage.

Sewerage (noun).—The works comprising a sewer system, pumping stations, treatment works, and all other works necessary to the collection, treatment or disposal of sewage; (adjective) having to do with the collection, treatment, or disposal of sewage.

Shave Hook.—A lead worker's tool used for shaving or cutting lead.

Shoulder Nipple.—A nipple somewhat longer than a close nipple. It has an unthreaded space of about ¼ in. between the threaded ends.

Shrunk Joint.—A joint made by shrinking a heated piece of pipe over the ends of two cool pipes.

Siamese Connection.—A wye connection used on fire lines so that two lines of hose may be connected to a hydrant or to the same nozzle.

Sill Cock.—A faucet, used on the outside of a building, to which the garden hose is usually attached.

Sink.—A shallow fixture, ordinarily with a flat bottom, which is usually used in a kitchen or in connection with the preparation of food. There are many types of special sinks but their purpose is indicated by a name prefixed before the name sink, such a slop sink, vegetable sink, etc.

Size and Length.—See *length.*

Sleeve.—A cylindrical tube surrounding a pipe or shaft.

Slip Joint.—A connection in which one pipe slides into another. The joint is made tight with approved gasket, packing, or caulking.

Slop Sink.—A deeper fixture than an ordinary sink; it is used for the receipt of slops.

Socket.—See *coupling.*

Socket Plug.—A plug with a recess in the face, into which a wrench will fit to turn the plug.

Soil Pipe.—A pipe through which liquid wastes carrying human excrement may flow. Also, a cast-iron pipe, with bell-and-spigot ends, used in plumbing to convey human excrement or liquid wastes.

Soil Stack.—A vertical soil pipe.

Soldering Iron.—A piece of copper, rectangular in shape, about ½ in. thick and 2 in. long, pointed at one end. Used to hold heat as it is applied to the solder.

Spigot.—The end of a pipe which fits into a bell. Also a word used synonymously with faucet.

Stack.—A general term used for any vertical line of soil, waste, or vent piping.

Stillson Wrench.—A special type of monkey wrench with toothed jaws for gripping pipe. Also called a pipe wrench.

Stock.—The tool which holds the dies in threading pipes, screws, bolts, etc.

Stop Cock.—A valve with a ground key.

Stop-and-waste Cock.—A stop cock so designed that when the supply of water is shut off a drain is opened through which the water in the pipe, on the side of the cock opposite the supply line, is drained to waste.

Storm Water.—That portion of the rainfall or other precipitation which runs off over the surface after a storm and for such a short period following a storm as the flow exceeds the normal or ordinary runoff.

Siphonage.—A suction created by the flow of liquid in pipes. A pressure less than atmospheric.

Sump.—A pit or receptacle at a low point to which liquid wastes are drained.

Surface Water.—That portion of a rainfall or other precipitation which runs off over the surface of the ground.

Sweating (When applied to pipes or fixtures).—The appearance of condensed moisture from the air on the surface of a cool pipe or fixture. The term is also used to indicate the soldering, welding, or brazing of metals.

Sweat Joint.—A soldered joint heated by a flame instead of a soldering iron.

Swedge.—To expand pipe by driving a wedge into it.

Sweep Fitting.—A fitting with a long radius curve.

Swing Joint.—A joint in a threaded pipe line permitting motion in the pipe.

Tampion.—A lead worker's tool of boxwood, shaped like a top, and used for swedging out the end of a lead pipe.

Tap (see *faucet*).—A tool used for cutting inside threads. To bore a hole into.

Tap Borer.—A plumber's tool used to open a lead pipe for a branch.

Tapped Tee.—A cast-iron bell-end tee with the branch tapped to receive a threaded pipe or fitting.

Trap.—A fitting or device so constructed as to prevent the passage of air, gas, and some vermin through a pipe without materially affecting the flow of sewage or waste water through it.

Trap Seal.—See *seal.*

Tray.—A fixture used in a laundry for washing; sometimes called a laundry tub.

Trimo Wrench.—Same as *stillson wrench.*

Tucker Fitting.—A cast-iron coupling, one opening of which is threaded for screw pipe and the other opening of which has a hub to receive the spigot end of a pipe.

Union.—A pipe fitting used for joining the ends of two pipes neither of which can be turned.

Unit Vent.—An arrangement of venting so installed that one vent pipe will serve two traps (see Fig. 99).

Vacuum.—An air pressure less than atmospheric.

Valve.—A device used for controlling the flow of liquid or gas in a line of pipe.

Vent.—A pipe or opening used for insuring the circulation of air in a plumbing system and for reducing the pressure exerted on trap seals. (For definitions of various types of vents, see Sec. 131.)

Volumeter.—A type of flush valve.

Washer.—(*a*) An annular ring threaded on the inside to be used as a lock nut; (*b*) a smooth, flat annular ring placed under a nut or bolt head to fill space or to protect the material under the nut or bolt; (*c*) a flat annular ring of soft material used in valves to prevent leakage.

Waste Pipe.—A pipe used for conveying liquid wastes not containing human excrement.

Waste Stack.—A stack used for conveying liquid wastes not containing human excrement.

Water-service Pipe.—See *service pipe.*

Wet Vent.—That portion of a vent pipe through which liquid wastes flow. In Fig. 111 the bathtub on the top floor discharges into a wet vent.

Yarning Iron.—A caulking tool similar to a cold chisel except that the plane of the point of the chisel is offset about 1 in. from the plane of the handle.

Yoke.—The collar by which a lead trap is secured to its support.

Yoke Vent.—Same as *loop vent.*

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